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WEATHER OF THE MONTH.

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ALFRED J. HENRY, Editor.

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MAY, 1923.

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A NEW FORM OF THERMOELECTRIC RECORDING PYRHELIOMETER.

By HERBERT H. KIMBALL and HERMANN E. HOBBS, Meteorologists.

[Weather Bureau, Washington, April 12, 1923.]

SYNOPSIS.

A thermopile consisting of 50 couples is made from 60Au–40Pd with 90Pt–10Rh wire 0.0016 inch in diameter, by electrically fusing the junctions. Alternate junctions are attached to, but electrically insulated from, two thin concentric copper rings. The inner ring has its upper surface painted black; the outer ring, white. Details of construction are given.

When exposed to solar radiation, the excess in temperature of the junctions attached to the blackened ring over those attached to the whitened ring produces an electric current, the voltage of which is very nearly proportional to the intensity of the solar radiation. With a solar radiation intensity of 1 gram-calory per minute per square centimeter of surface the current generated has a voltage of between 9 and 10 millivolts.

A type RM Engelhard recording voltmeter is employed to obtain continuous records of the solar radiation intensity. A sample record and illustrations of the thermopile are given.

THERMOELECTRIC PYRHELIOMETERS.

The use of a thermopile for measuring the intensity of solar radiation is not new. The Ångström pyrheliometer [1] and the Smithsonian pyranometer [2] are well-known instruments of this type.

Recently Dorno [3] has described an instrument employing the thermopile for obtaining continuous records of the intensity of direct solar radiation. He also refers to an adaptation of the thermopile described in an earlier paper,[4] for continuously recording the total radiation (direct solar + diffused sky radiation) received on a horizontal surface. Both these instruments develop thermoelectric current of such low voltage that the photographic registration of the deflection of a sensitive galvanometer is the only practicable way of obtaining a record. In his later paper, however, Dorno [5] refers to a "miniature thermocouple of 12 elements of special alloys, which, when fully exposed to the sun, gives about 4 millivolts, a power which would enable us to replace the photographic by a mechanical registration."

THE WEATHER BUREAU THERMOELECTRIC RECORDING PYRHELIOMETER.

The Weather Bureau, in cooperation with the United States Bureau of Standards, has recently designed, and its mechanicians have constructed, a very convenient form of thermoelectric recording pyrheliometer, which, when exposed to full sunshine, is capable of developing about 15 millivolts. It seems desirable, therefore, to describe it in some detail.

[1] Ångström, Knut., The absolute determination of the radiation of heat with the electric compensation pyrheliometer, with examples of the application of the instrument. Astrophysical Journal, vol. 9, pp. 332–346.

[2] Abbot, C. G., Fowle, F. E., and Aldrich, L. B., Annals of the Astrophysical Observatory of the Smithsonian Institution, vol. 4, pp. 65–76.

[3] Dorno, C. Progress in radiation measurements. MO. WEATHER REV., Oct. 1922, vol. 50, pp. 515–521.

[4] Ångström, A., and Dorno, C., Registration of the intensity of sun and diffused sky radiation. MO. WEATHER REV., March, 1921, vol. 49, pp. 135–138.

[5] loc. sit., p. 516.

Thermoelectric couples.—Experience with the pyrgeometer [6] has shown that while silver-bismuth thermoelectric junctions are highly efficient, they are difficult to solder, and the bismuth wire is liable to break with ordinary handling of the instrument. Upon the advice of the Director of the Bureau of Standards a combination of the alloys 60Au–40Pd with 90Pt–10Rh was tried.

Under test at the Bureau of Standards, a thermocouple made up of these two alloys gave the following electromotive force when the fixed junction was in ice and the other junction was at the temperature indicated.

Temperature, °C.	E. M. F., millivolts.
100	3.68
60	2.12
25	.85
−40	−1.24

The following equation gives the relation between temperature and the electromotive force if E is in microvolts and t in degrees centigrade.

$$E = 32.975t + .03881t^2$$

The mean temperature-resistance coefficients per degree centigrade between 0° and 100° were found to be—

Wire.	Temp.-resist. coefficient.
Platinum-rhodium	0.00165
Gold-palladium	.000446

Measurements at the Weather Bureau gave the resistance per linear foot of wire 0.0016 inch in diameter at room temperature as follows:

	Ohms.
Platinum-rhodium	50.7
Gold-palladium	54.6

It thus appears that while, as compared with Bi-Ag, these alloys give little more than half the E. M. F., they have less than half the resistance, and should give slightly better current sensitivity. Moreover, these alloys are very ductile, which permits them to be drawn out to a small diameter. They also fuse readily, making a neater junction than soldering.

Thermopiles.—Heretofore in the design of multiple thermocouple devices for measuring radiation it has been the practice to secure the needed surface for the larger number of junctions by resorting to the use of several parallel strips with alternating black and bright surfaces. The disadvantages of such construction and the difficulties of computing the performance of such forms have been obviated by the use of the annular ring and disk arrangement. This greatly improved and simplified design, which also secures proper exposure for the composite surface, was suggested by Professor Marvin, and is easily understood from the description which follows.

[6] Kimball, H. H., Nocturnal radiation measurements. MO. WEATHER REV., Feb., 1918, 46: 56–70.

On the left in Figure 1 is shown the upper surface of the black ring, *C*, and the white ring, *D*. The space inside the black ring is filled by a whitened disk, and the rings are mounted inside a bakelite ring, also painted white. The upper surfaces of the disk, the two rings, and the bakelite ring are in the same plane.

On the right in Figure 1 is shown the under side of the rings *C* and *D* with the wires forming the couples attached. It will be noted that each ring rests on the ends of three wire supports to which it is cemented by bakelite lacquer. The central disk is supported on a post rising from a metal strap attached to the lower side of the bakelite ring.

The space between the disk and the inner ring *C*, between the two rings, and between the outer ring *D* and the bakelite ring, should be just sufficient to insure insulation.

Two thermopiles were made up of wire 0.0008 inch in diameter. No. 1 had 20 couples, and a resistance at room temperature of 137 ohms. No. 2 had 40 couples so arranged that they could be connected in series, or in two parallel series of 20 couples each. The resistance of No. 2_s (40 couples in series) was 326 ohms, and of No. 2_p (two parallel series of 20 couples each), 82 ohms.

A circular projection, *P*, on the surface of the block, just fills the space between these two rings and holds them in place.

Single junctions of the two wires are made, preferably while the wire is still attached to the spools, by twisting the ends together, and electrically fusing them. One terminal of the circuit carrying the heating current may be attached to tweezers, between the points of which the twisted wire is clasped. The other terminal, consisting of a finely sharpened carbon pencil, is brought in contact with these wires. A 110-volt circuit, in which the current is stepped down by resistance to about 1 ampere, will burn the wires back to the tweezers and there form a small bead. They are then cut off at the proper length and laid aside until the required number of junctions has been prepared.

The surfaces of the copper rings *C* and *D* are thoroughly polished, cleaned, and lacquered with bakelite lacquer. For cementing the junctions to the rings bakelite lacquer, insulating bakelite varnish, or shellac may be used. The junctions are attached to the inner ring *C* by pressing them against the cement, one junction for each alternate division on the brass block, and then covering the junction with the cement.

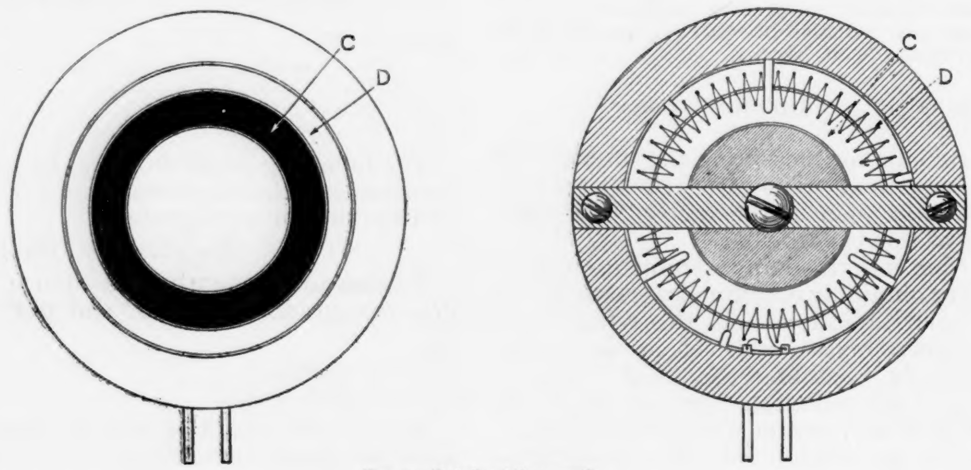

FIG. 1.—Details of thermopile.

When exposed in a diaphragmed tube to solar radiation of an intensity of 1.37 gram-calories per minute per square centimeter, No. 1 developed an E. M. F. of 5.10 millivolts; No. 2_p, 5.49 millivolts; and No. 2_s, 10.65 millivolts. The moving coil in the voltmeter employed had a resistance of about 91 ohms. Therefore, No. 2_p, on account of its low resistance, gave a current of much greater amperage, and consequently caused a greater deflection of the voltmeter, than Nos. 1 and 2_s.

Thermopiles Nos. 3, 4, and 5 were made of wire 0.0016 inch in diameter, and with 50 couples in series. The construction of these thermopiles will now be described.

Details of construction.—Figure 2 shows a brass block with its upper surface divided by radial lines into 100 equal spaces. On this block are placed the two copper rings, *C* and *D*, shown in Figure 1, and which have the following dimensions:

	Inches.
Thickness (No. 25, U. S. standard sheet steel gauge)	0.021
Inner diameter of *C*	0.88
Outer diameter of *C*	1.23
Inner diameter of *D*	1.25
Outer diameter of *D*	1.52

These dimensions give a surface area of about 0.57 square inch or 3.67 square centimeters to each ring.

The wires of the individual couples having been identified, the loose end of an Au-Pd wire of one couple is twisted to the Pt-Rh wire of an adjacent couple, fused, and then fastened to the outer ring *D*, a junction for each alternate space on the block, using the spaces left vacant by the junctions attached to the inner ring.

The fusing of these second junctions is effected as follows: The brass arm *A*, Figure 2, revolves about the central post *X* of the brass block and is lacquer coated or insulated except for a small spot on the lower point of the end at *E*. The ring *D* is also lacquer coated. One terminal of the 110-volt circuit is placed in contact with the lower surface of the brass block; the other, or carbon terminal, is brought in contact with the twisted wires. If the lacquer-free spot on the arm *A* is also in contact with the wires, the circuit will be completed between the terminals and the wires will burn back to the end of the arm at *E*, usually forming a small bead. This arrangement insures uniform length of the wires between the junctions.

Care must be taken to insure insulation of the junctions from the rings, and the wires from each other except at the junctions. The wires are coated with lacquer, but care is taken to separate them as much as possible.

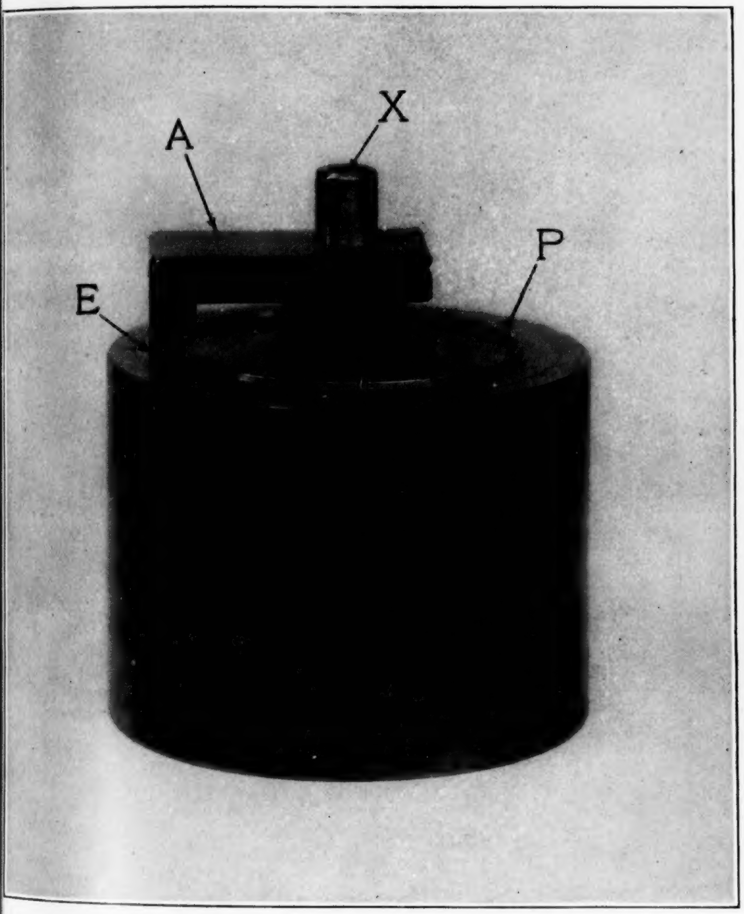

FIG. 2.—Tool employed in fusing thermocouples.

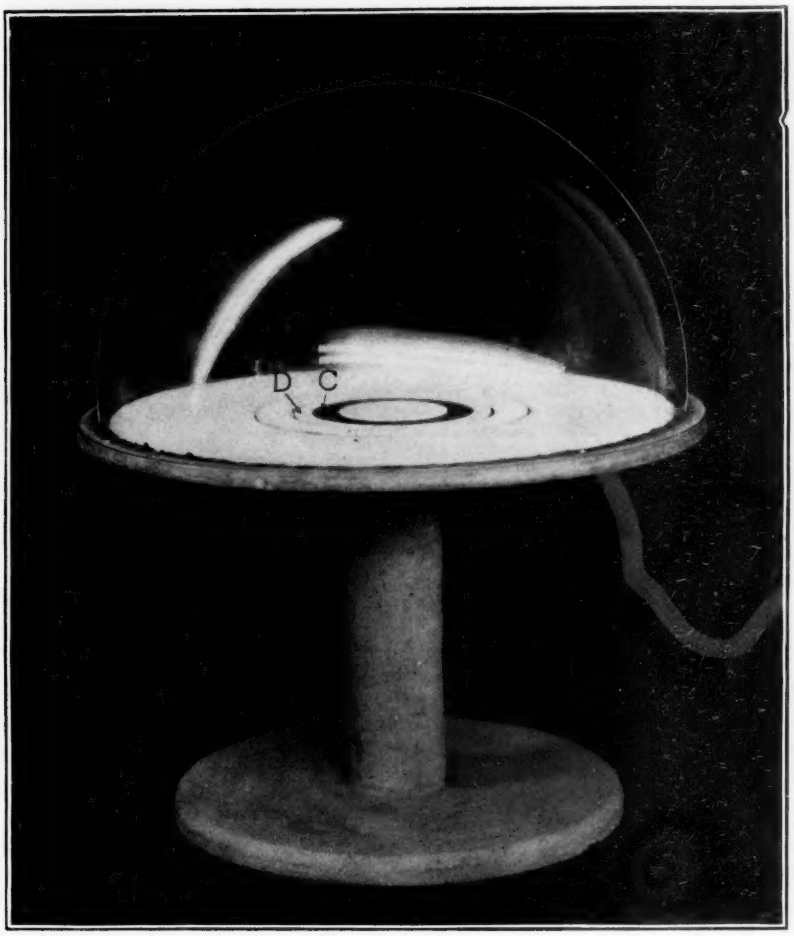

FIG. 3.—Thermoelectric pyrheliometer.

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The two rings carrying the thermopile may now be mounted in a bakelite ring as shown in Figure 1, the upper surface of the inner copper ring *C* painted black, using a mixture of lampblack in alcohol, with just enough lacquer to cause the lampblack to adhere to the metal surface; and the inner disk, the outer copper ring *D*, and the upper surface of the bakelite ring painted white, using a mixture of zinc-oxide in grade 3 Zapon lacquer, or cellulose lacquer.

Through the courtesy of the Director of the Bureau of Standards, thermopile No. 3 had the upper surface of the outer ring *D* very neatly covered with a thin coating of white enamel, which was slightly thicker at the center than near the edges of the ring, giving the surface a somewhat rounded contour. Magnesium oxide produced by the combustion of magnesium shavings, was then deposited on the white enamel. After a time, and especially when exposed out of doors but under a glass cover, the magnesium oxide gradually became less white,[7] changed to a liquid, and finally dried out, leaving a hard scaly deposit like varnish.

a glass hemisphere 4½ inches in diameter is cemented. A screw through a sleeve attached to the lower side of the brass ring secures the ring and glass cover to the support. They serve to protect the thermopile from wind and rain.

During the warm part of the year, with a sudden change from warm and moist to cool weather, or even with a change from day to night temperatures, moisture will sometimes deposit on the inside of the glass cover, which must then be removed and the moisture wiped off.

Suitable leads from the terminals of the thermopile connect with wires leading to the terminals of the register.

THE RECORDING APPARATUS.

The Weather Bureau makes use of an Engelhard type RM recording voltmeter in obtaining records of radiation intensity. At minute intervals a depressor bar presses the index arm against a record sheet under which is an inked pad, making a dot on the sheet. By using pads inked with different colors it is possible to so arrange the

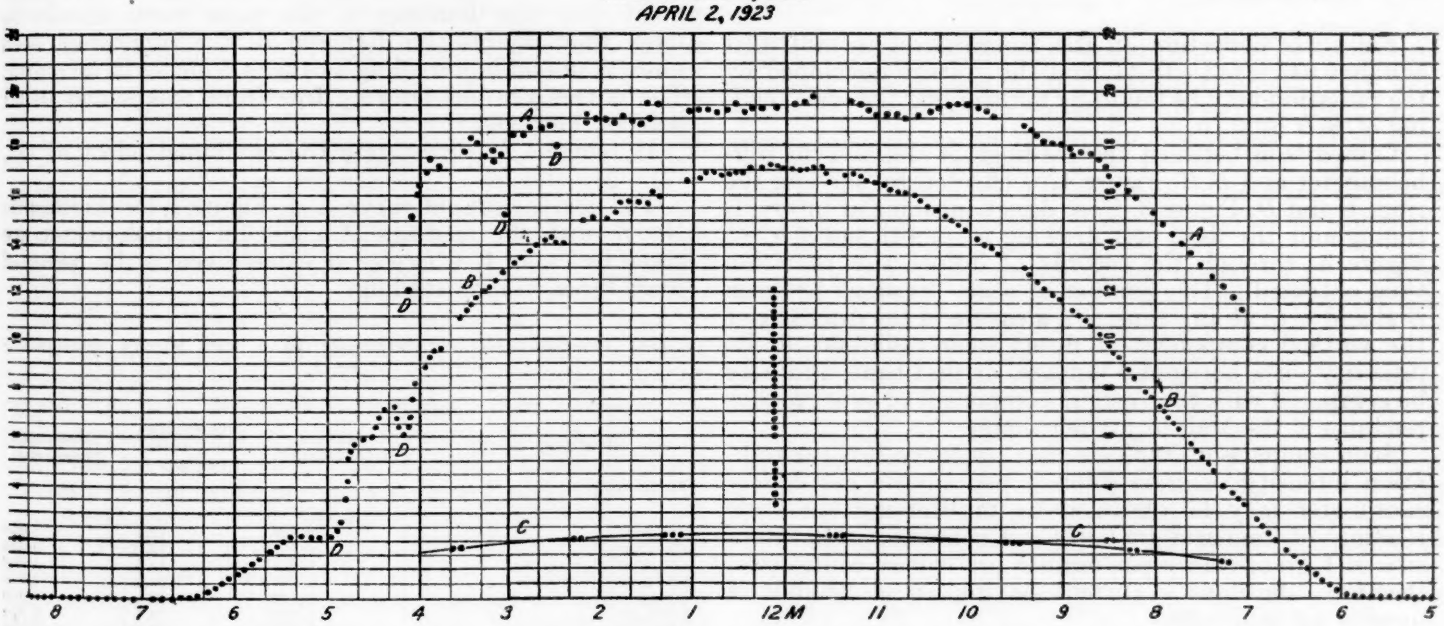

FIG. 4.—Solar radiation record.

This was the case with thermopiles Nos. 1 and 2, which were also coated with magnesium oxide. For this reason zinc oxide paint was substituted for magnesium oxide smoke, although the latter is less selectively reflective than the former. Thermopiles Nos. 4 and 5 have the zinc oxide paint applied directly to the copper surface of the ring D.

Mountings of the thermopile.—For the measurement of solar radiation the thermopile is mounted in two ways: (1) For the measurement of the intensity of direct solar radiation it is mounted in the clock-driven, equatorially mounted, diaphragmed tube designed for the Marvin pyrheliometer;[8] (2) for the measurement of the total solar and sky radiation received on a horizontal surface, the mounting is as shown in Figure 3. The thermopile in its bakelite mounting rests in an open brass box, at the top of the upright support. Surrounding this box is a brass ring, containing a groove in its upper surface, into which

circuits that more than one thermopile may register on the sheet. The interval between record dots by the individual thermopiles in this case will be more than one minute.

On April 2, 1923, the upper row of dots, *A A*, Figure 4, was obtained by exposing thermopile No. 5 normally to the direct solar rays when mounted in a diaphragmed tube. The lower row of dots, *B B*, was obtained by exposing thermopile No. 4 horizontally, under a glass cover, to the total radiation from the sun and sky. Full-scale deflection represents a current intensity of 45 microamperes. The value of the scale divisions in millivolts depends upon the resistance of the thermopile, the moving coils of the voltmeter, the leads, and the swamping resistance.

For thermopile No. 5, with which the record *A A*, was obtained, the total resistance of the circuit was approximately as follows:

	Ohms.
Thermopile and leads	86
Moving coils of voltmeter	60
Swamping resistance	150
Total resistance	296

[7] Dorno (loc. cit., p. 517) refers to this same deterioration of magnesium oxide with extended exposure.

[8] See Fig. 1 Marvin pyrheliometer and auxiliary apparatus, MO. WEATHER REV., Nov., 1919, vol. 47, opp. p. 769.

Full-scale deflection on the record sheet in millivolts equals $0.045 \times 296 = 13.32$. Since there are 22 numbered divisions on the sheet, the voltage developed by the solar radiation at any time may be found by multiplying the scale reading of *A A* by 0.605.

Comparison of the curve *A A* with simultaneous readings of the Marvin pyrheliometer indicates that the solar radiation intensity in gram-calories per minute per square centimeter of surface normal to the incident solar rays may be obtained by multiplying scale readings on the curve by 0.064. A solar radiation intensity of 1 gram-calory per minute per square centimeter, therefore, develops a current having an electromotive force of 9.45 millivolts.

For thermopile No. 4, with which the record *B B* was obtained, the total resistance of the circuit was approximately as follows:

	Ohms.
Thermopile and leads	83
Moving coils of voltmeter	60
Swamping resistance	200
Total resistance	343

Full-scale deflection on the record sheet in millivolts equals $0.045 \times 343 = 15.44$, and the voltage developed by the radiation may be found by multiplying the scale reading of *B B* by 0.70.

Comparison between the readings of the Marvin pyrheliometer and *B B*, Figure 4, is effected by shading the rings *C* and *D*, Figure 3, from direct sunshine at intervals throughout the day, and drawing a smooth curve *C C*, Figure 4, through the records of diffuse sky radiation thus obtained. The number of scale divisions between *B B* and *C C*, at any time, is a measure of the intensity of the vertical component of direct solar radiation, or its intensity on a horizontal surface, at that time, and may be compared with the vertical component of synchronous readings of the Marvin pyrheliometer.

Such comparisons indicate that for curve *B B* the radiation intensity in gram-calories per minute per square centimeter may be obtained by multiplying the scale readings of the curve by 0.073. A solar radiation intensity of 1 gram-calory per minute per square centimeter, therefore, develops a current having an electromotive force of 9.6 millivolts.

It will be noted that at noon of April 2 the sky radiation (2.3 scale divisions on the record sheet) was about 13.5 per cent of the total radiation received on a horizontal surface (17.0 scale divisions).

From the data given above we may compute that shortly before noon on April 2 the blackened ring *C* of thermopile No. 5 was receiving solar radiation at the rate of 1.30 gram-calories per minute per square centimeter, or 4.77 gram-calories per minute upon the 3.67 square centimeters of its surface. Reduced to units of work, this equals 0.33 watts per second.

The current generated by the thermopile was about 40.7 microamperes, with an E. M. F. of 12.05 millivolts, which equals 0.00000049 watts, or about 0.0000015 of the heat energy received by the blackened ring.

On Figure 4, the depressions marked *D* on curves *A A* and *B B* show the effects of passing bands of cirrus clouds.

The vertical row of dots just after the 12 m. time line were made at 12, noon, apparent time.

Accuracy of the record.—Records obtained by means of thermoelectric pyrheliometers are subject to the following errors:

(1) As shown by the Bureau of Standards tests, the E. M. F. generated is not strictly proportional to the difference between the temperature of the junctions attached to the black and the white rings, respectively. The efficiency of the thermopile appears to increase with temperature difference, and presumably with the temperature of the pile.

(2) The resistance of all the wires except that in the swamping resistance increases with temperature, but at a slower rate than the E. M. F. increases.

(3) It is not probable that the difference in the temperature of the junctions attached to the black and the white rings, respectively, is strictly proportional to the intensity of the radiation to which they are exposed.

(4) The hemispherical glass cover over the horizontally exposed thermopile may cause irregularities in the record unless it is exactly spherical, is free from flaws of all kinds, and is large enough so that the caustic curve caused by the reflection of light from its internal surface does not fall on either of the rings.

On account of the small diameter of these rings (outer diameter of the white ring equals 1.52 inches), the requirement that the diameter of the glass cover should be more than double the diameter of the ring[9] has been more than met in providing a cover 4.5 inches in diameter. The covers are not entirely free from waves and other defects, however.

It remains to investigate the combined effect of (1), (2), (3), and (4).

The comparisons of curve *A A*, Figure 4, for thermopile No. 5, with the readings of a Marvin pyrheliometer are given in Table 1, where each value given is the mean of from three to nine readings.

TABLE 1.—*Comparison of thermopile No. 5, with Marvin pyrheliometer No. 3.*

Hour angle of sun.	Marvin pyrheliometer.	Thermopile No. 5 scale reading.	Pyrheliometer / Thermopile.
	Gr.-cal.		
4:59 a. m.	0.729	11.5	0.0634
4:38 a. m.	0.816	13.0	0.0628
4:05 a. m.	0.979	15.1	0.0648
3:28 a. m.	1.091	17.2	0.0634
2:20 a. m.	1.222	19.2	0.0636
0:20 a. m.	1.309	19.7	0.0664
2:32 p. m.	1.194	18.7	0.0638
3:44 p. m.	1.074	17.2	0.0624
Mean			0.0638

A slight tendency is noted for the thermopile to read relatively low in the middle of the day.

Curve *B B*, for thermopile No. 4, exposed horizontally under a glass cover, when compared with the vertical component of the readings of the Marvin pyrheliometer, shows some distortion of the record due to imperfections in the glass cover. For example, between 2 p. m. and 4 p. m., apparent local time, curve *B B* is relatively higher than between 8 a. m. and 10 a. m. This distortion disappeared in later records when a better glass cover was used.

It is possible that an annual variation may be found in the ratio Marvin pyrheliometer/Thermopile. Further use of the thermopiles is necessary to answer this question.

Also, it has not yet been demonstrated how well the white paint used on the ring *D* will withstand sunlight.

The authors believe, however, that the thermoelectric pyrheliometer will prove a reliable and useful instrument.

[9] Miller, Eric R., Internal reflection as a cause of error in the Callendar bolometric sunshine receiver. Monthly Weather Review, 43: 264–266

SUNSPOTS AND TERRESTRIAL TEMPERATURE IN THE UNITED STATES.[1]

By ALFRED J. HENRY, Meteorologist.

[Weather Bureau, Washington, April 16, 1923.]

SYNOPSIS.

This study has for its object a determination of the magnitude of fluctuations in terrestrial temperature in the United States that might be attributed to changes in the intensity of solar radiation; a less important object is to discover whether variations in the annual mean temperature of a limited region may be safely taken as representative of a much larger area in which the smaller area may be situated.

The method followed was that of determining for one each year the departure from the normal of the annual mean temperature for that year, combining these departures to form group means, etc.

The outstanding feature of the annual deviations for the United States is the evidence of short period variations within the 11-year sun spot cycle. For a time there seems to have been alternating warm and cold years and again the cycle, cold-warm would be completed in three, four, or five years. The magnitude of these short period fluctuations of course varies in an irregular manner but it must be remembered that on the average of nearly 100 years the average annual deviation of the temperature from the normal in the United States is close to 0.7° F.

For the period 1870–1921, the parallelism between terrestrial temperatures and variations in sun spots is fairly well marked, a heat maximum corresponding to a minimum of sun spots and vice versa. Previous to that period, however, the parallelism is not so good and there are several cases where the temperature variation is in the opposite sense to that expected. The average deviation for the 10 epochs of minimum spots comes out as a small fraction of a degree Fahrenheit in a negative sense because of the low temperature at spot minimum of 1843 and 1856, respectively. For the 10 epochs of spot maximum, 1816 and 1837 were unusually cold as was to be expected, on the other hand 1870 a year of a large number of spots high temperatures prevailed, as was also the case in 1848, 1860, and 1906.

As the writer has previously stated it is next to impossible to disentangle the network of influences which produce terrestrial temperature changes. Until some means of allowing for the influence of the secondary circulation (the movement of cyclones and anticyclones) is found it is hopeless to seek for effects of changes in the intensity of solar radiation in the Temperate Zone of the Northern Hemisphere.

In announcing the subject of this paper I feel inclined to apologize for threshing over so much old straw; nevertheless it seems worth while to make a brief study of the subject, using only the homogeneous system of temperature observations of the United States Weather Bureau and in addition those collected and reduced by the Smithsonian Institution for the period ending with 1870. Hitherto progress in arriving at unequivocal results has been retarded by the lack of homogeneous temperature data for extended regions as well as to other causes. Unfortunately large portions of the earth's surface are without records of long series temperature observations made under standard conditions of exposure and with standard instruments, and this drawback is more serious than is generally realized. Some idea of the paucity of dependable observations may be had when it is remembered that so late as the year 1910, when the first volume of Reseau Mondial became available there were but 111 normal temperature records in a zone 60° wide encircling the globe with the Equator as its center. That number rose to 134 for the 1914 volume, the last one received. Many of these stations, however, are grouped in India and the adjacent islands. The great tropical areas of Africa and South America are almose devoid of meteorological stations except for narrow fringes of the coast. At least five-sixths of the Tropics is composed of a water surface and is not therefore adequately represented by meteorological stations.

I have confined my work almost wholly to the observational material for the United States, or substantially that part of the earth's surface between 75° and 125°, west longitude, and the parallels of 30° to 50°, north latitude.

At the outset it has been assumed that when the temperature of any considerable part of the earth's surface is decidedly above or below the normal, it is reasonable to attribute that condition to changes in the intensity of solar radiation. My first step was therefore to obtain the annual deviation of the temperature from the normal for as many points as possible within the above-described area.

In the early part of the nineteenth century meteorological observations in the United States were confined to the eastern seaboard and near-by places. By 1816 observations were available for but 12 points all in the East. The number increased rather slowly in the ensuing 10 years with this important exception: In the early twenties the Surgeon General of the Army directed the taking of meteorological observations at Army posts, some of which were on the western frontiers. By 1830 the total number of observing stations had risen to 52, practically all east of the Rocky Mountains. That number was further increased to 94 in 1859, just previous to the War between the States; it fell off during that war and was about 70 when the Federal Government organized a weather service late in the year 1870.

I have used the annual means published in Weather Bureau Bulletin S, 1873 to 1905, and the series was brought down to date by applying a correction to the published means found in the annual reports and the MONTHLY WEATHER REVIEW to reduce them to means deduced from 24 hourly observations. I make this explanation in the interest of those who may wish to bring the temperature data of Bulletin S down to date. The published means for the years 1906–1922 have been deduced from the daily extremes; appropriate corrections to reduce to true means are given in Bulletin S, Table 1.

The annual deviation for each year beginning with 1780 is given in Table 1 below. No attempt has been made to weight the earlier years on account of the few observations used but the number of stations used in obtaining the deviation is given. Little importance is attached to the early part of the record and it is given simply for what it is worth.

The mean annual deviation of temperature for the United States as a geographic unit, counting from 1826 only, is very close to 0.7° F. (0.4° C.). The greatest positive deviation in the ninteenth century was 2.9° F. (1.6° C.) in 1828, the greatest negative was 2.6° F. (1.4° C.) in 1836. These, the greatest deviations in a century of observations, fall within less than 10 years of each other. Comparing the above dates with the general temperature distribution in the North Temperate Zone, for example, it would appear that for the much greater area the maximum of temperature occurred in 1822 and for the Tropics in 1833. The minimum temperature for the North Temperate Zone occurred in 1816, but in the Tropics it was deferred until 1837, the same year as in the United States.

[1] Presented before American Meteorological Society at Washington, D. C., Apr. 16, 1923.

TABLE 1.—*Mean annual deviation of temperature from normal for the United States as a geographic unit.*

[Figures without sign are plus.]

Number of stations.	Year.	Mean annual deviation, °F.	Number of stations.	Year.	Mean annual deviation, °F.	Number of stations.	Year.	Mean annual deviation, °F.
1	1750	−0.9	7	1812	−2.2	67	1867	0.0
1	1751	0.8	9	1813	0.4	68	1868	−0.9
1	1752	1.4	9	1814	0.0	66	1869	−0.5
1	1753	0.9	8	1815	−1.0	67	1870	1.7
1	1754	1.9	12	1816	−1.7	68	1871	0.9
1	1755	−2.3	13	1817	−1.5	90	1872	−0.8
1	1756	1.1	12	1818	−0.6	82	1873	−0.5
1	1757	−0.2	11	1819	1.0	82	1874	0.6
1	1758	−1.6	14	1820	−0.1	82	1875	−1.2
1	1759	−0.8	14	1821	−0.6	82	1876	−0.1
1	1767	0.5	13	1822	0.9	82	1877	0.9
1	1768	−1.2	14	1823	−0.6	82	1878	1.4
1	1769	−0.9	14	1824	0.6	82	1879	0.9
1	1770	−0.3	14	1825	2.0	82	1880	−0.4
1	1771	−0.9	32	1826	1.8	82	1881	0.7
1	1772	−0.2	38	1827	0.7	82	1882	0.2
1	1773	2.0	40	1828	2.9	82	1883	−0.7
1	1774	0.2	40	1829	−0.6	82	1884	−0.5
1	1775	1.7	52	1830	1.7	82	1885	−0.4
1	1776	0.8	53	1831	0.4	82	1886	−0.4
1	1777	−1.7	55	1832	0.1	82	1887	0.2
1	1778	....	62	1833	0.4	82	1888	−0.3
1	1779	....	61	1834	0.6	82	1889	0.7
1	1780	0.7	65	1835	−1.6	82	1890	0.4
2	1781	1.8	60	1836	−2.6	82	1891	0.1
1	1782	0.1	63	1837	−1.8	82	1892	−0.6
2	1783	0.9	63	1838	−1.6	82	1893	−0.9
1	1784	−1.7	67	1839	0 0	82	1894	0.1
1	1785	−1.3	74	1840	0.0	82	1895	−0.8
2	1786	−0.5	75	1841	−0.5	82	1896	0.6
2	1787	0.3	79	1842	0.1	82	1897	0.2
3	1788	−0.1	84	1843	−1.2	82	1898	0.1
3	1789	−0.1	82	1844	−0.2	82	1899	−0.3
5	1790	0.0	86	1845	0.3	82	1900	1.3
5	1791	0.8	76	1846	1.3	82	1901	0.4
5	1792	−0.5	73	1847	−0.3	82	1902	0.1
4	1793	2.1	71	1848	0.4	82	1903	−0.6
4	1794	1.3	70	1849	−0.3	82	1904	−0.5
5	1795	1.3	71	1850	0.2	82	1905	−0.4
6	1796	−0.7	76	1851	0.3	82	1906	0.4
4	1797	−0.7	72	1852	0.1	82	1907	−0.2
5	1798	0.4	67	1853	0.4	82	1908	0.6
5	1799	−0.3	77	1854	1.1	82	1909	0.1
5	1800	0.8	86	1855	0.0	82	1910	0.9
5	1801	1.5	93	1856	−1.8	82	1911	0.4
5	1802	2.1	86	1857	−1.3	82	1912	−0.9
5	1803	1.2	86	1858	0.2	82	1913	0.5
5	1804	−0.3	94	1859	−0.3	82	1914	0.6
5	1805	1.6	82	1860	0.6	82	1915	0.4
5	1806	−0.3	70	1861	0.4	82	1916	−0.5
6	1807	−1.1	61	1862	−0.1	82	1917	−1.3
6	1808	−0.4	68	1863	0.1	82	1918	0.5
6	1807	−1.0	67	1864	0.0	82	1919	0.4
7	1810	0.0	64	1865	1.0	82	1920	−0.3
7	1811	1.0	57	1866	−0.3	82	1921	2.4

fluctuations in the entire series of years. The small table below presents the annual deviations for the years in question. The large deviations shown in that table can not be very closely associated with the spottedness of the sun, except that those for 1837 synchronize with the epoch of maximum spots; elsewhere on the globe, however, better agreement is found.

The figures of Table 1 are graphically shown in Figure 1. Epochs of spot minimum are shown by the arrows at the top of the figure.

TABLE NO. 2.—*The extremes of mean annual temperature in United States in the nineteenth century.* [° F.]

Warm years.	Deviation.	Cold years.	Deviation.
1825	+2.0	1835	−1.6
1826	+1.8	1836	−2.6
1827	+0.7	1837	−1.8
1828	+2.9	1838	−1.6
Mean	+1.7		−1.9

Variability in the length of sun-spot cycle.—Köppen and others early recognized that the sun-spot cycle varied irregularly in length. This variability has been and is the source of much difficulty in determining whether or not there is a connection between the two variables—spottedness of the sun and terrestrial temperature.

Schuster [2] with a view of discovering whether or not periodicities could be found in sunspots, subjected all available data thereon to a critical analysis by the process of the periodogram. On dividing the record of sun spots for the period 1749–1899 into two approximately equal parts and analyzing the parts separately he was able to infer that between 1750 and 1820 the 11-year period, though existing, had only a slight intensity, being quite overpowered by two others with periods of about 13¾ and 9¼ years. He also arrived at the conclusion that these two periods were active successively rather than simultaneously, and that of the two periods the one of 9 years was the most important as regards the obervations previous to the maximum of 1788, while that of 13 and 14 years is brought in through the variations observed between 1788 and 1829.

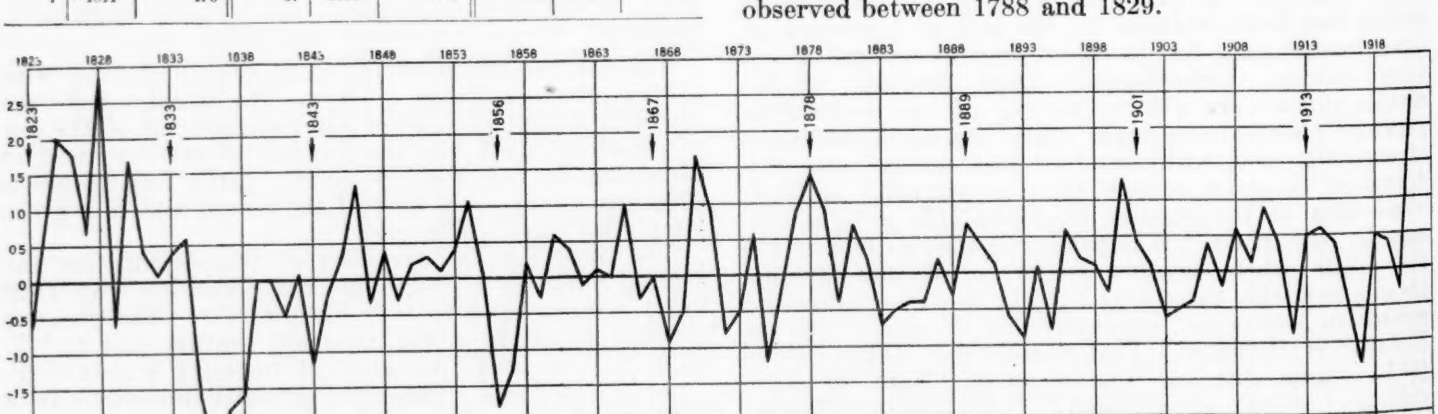

FIG. 1.—Annual deviation of temperature, United States, 1823–1921. Disregard arrows at bottom.

A series of warm years in the United States began in 1825 and prevailed uninterruptedly until 1829; that year was colder than the average by 0.6° F.; then followed five consecutive years with temperature somewhat above the average. A change to lower temperature set in in 1835, continuing through 1836, 1837, and 1838, thus forming the most striking series of temperature

It would seem as if the more or less regular variations showing maxima of intervals of rather more than 9 years were succeeded about 1788 by three unequal but long periods of 17.1, 11.2, and 13.5 years, respectively, and these afterward settled down to a fairly regular

[2] Schuster, A.: On the periodicities of sun spots, *Phil. Trans. Roy. Soc. of London*, A 206, pp. 69–100, 1906.

periodicity of 11.1 years. According to Schuster there is evidence of a number of definite periods. He determined with considerable accuracy the length of three, as follows: 4.79, 8.36, and 11.25 years, respectively.

Before commenting upon the figures of Table 1 it will be helpful to briefly review the results achieved by investigators of the sun spot-terrestrial temperature relations.

The studies of Köppen,[3] beginning with his original paper of 1873 and concluding with his recent paper of 1914, stand in the first rank as regards thoroughness of treatment and the amount of data made available.

He used material from 403 stations distributed over the whole earth, and these he classed by climatic zones. His original conclusions were that in the Tropics parallelism between the variations in the mean annual temperature and those of sun spots is fairly well marked, also that the heat maximum of the Tropics occurs on the average nine-tenths of a year before the corresponding sun-spot minimum and is more retarded with distance from the Equator. The temperature minimum in the Tropics occurs about the time of spot maximum.

In his most recent work this retardation is not so much in evidence as it was in the period 1820–1850, and he now concludes that both within and without the Tropics the heat maximum coincides with spot minimum; in the heat minimum, however, there is in the extra-tropics a slight retardation 0.9 year toward spot maximum.

Newcomb,[4] on the other hand, finds that the maximum of temperature precedes the minimum of spots by 0.3 year and that the minimum of temperature follows the maximum of spots by 0.65 year.

Nordman[5] (1903), using data of 13 stations ranging in latitude from 19 S. to 23 N., concluded that—

> The mean temperature of the earth is subject to a period substantially equal to that of sun spots; the effect of these spots is to diminish the mean temperature of the earth; that is to say, the curve which represents the variations of the latter is parallel to the inverted curve of frequency of sun spots.

Angot,[6] using 16 series of observations, practically the same as those used by Nordman, and treating them by a more rigorous method, concludes as follows:

> In summing up we find that of the 16 series thus studied 14 give for (a) [a constant characteristic of each station and of each period of solar activity] a negative value and 2 a positive value; the probability is then, according to these observations, 7 to 1 that an increase in the number of sun spots is accompanied by a diminution of the temperature and inversely.
>
> By giving to the values of (a) deduced from observations of the various stations, weights proportional to the number of series, we obtain for the final value of (a) —0.0033 C. in the value of the mean annual temperature.

Newcomb (loc. cit.), by a rigorous mathematical method, concludes from an examination of a relatively large number of observations:

> 1. A study of the annual departures over many regions of the globe in equatorial and middle latitudes shows consistently a fluctuation corresponding in period with that of solar spots. The maximum fluctuation in the general average is 0.13 C. on each side of the mean for the tropical regions. The entire amplitude of the change is therefore 0.26 C., or somewhat less than half a degree Fahrenheit. As this fluctuation has ample time to produce its entire effect on the earth, we conclude from it that the corresponding fluctuation in the sun's radiation is 0.2 of 1 per cent on each side of the mean.

Mielke (1913)[7] in an exhaustive study confirmed in large measure the results reached by Köppen in 1873.

Summarizing the foregoing it appears that the weight of evidence is in favor of the existence of a variation in the air temperature of the globe corresponding roughly with that of the spottedness of the sun, an increase in spots corresponding with diminished terrestrial temperatures and vice versa. The amplitude of the variation, is, however, small as has been shown by several investigators and amounts to less than a degree centigrade in the mean of the year.

It is best exemplified in the tropics and is uncertain and difficult to trace in temperate latitudes.

The annual deviations in the United States as shown in Table 1 may now be considered. During the 111 years, 1810–1921, specifically studied the average length of the interval between the epochs of spot minima and the immediately following spot maxima was 4.7 years and the average interval between epochs of minima was 11.5 years.

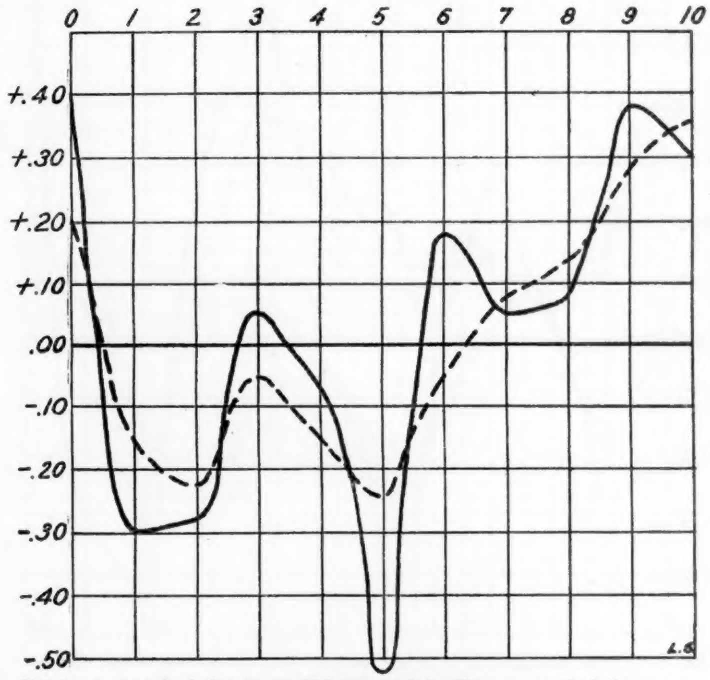

FIG. 2.—Annual deviation in an 11.1-year period. The unsmoothed figures are platted in the full curve, the broken curve is from smoothed values.

For convenience in discussing the data I have assumed a constant sun-spot cycle of 11.1 years and have tabulated the annual departures in horizontal rows of 11 vertical columns in the manner used by some meteorologists in detecting periodicities of a known or suspected length.

The figures appear in the table below and the means of the vertical columns form the curves of Figure 2 the full line being the unsmoothed means and the broken line the same values smoothed by the common formula, $b=\left(\frac{a+2b+c}{4}\right)$.

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[3] Köppen, W.: Über mehrjährige Perioden der Witterung, insbesondere über die 11-jährige Periode der Temperatur. *Zeitschr. der Ostereichischen Gesellschaft fur Meteorologie*, VIII, 1873, XV, 1880, XVI, 1881: *Met. Zeit.* VIII, 1891, XXXI, 914.

[4] Newcomb, S.: A search for fluctuations in the sun's thermal radiation through their influence upon terrestrial temperature, *Trans. Amer. Phil. Soc.*, Philadelphia, 1908.

[5] Nordman Ch.: *Comptes Rendus* CXXXVI, Paris 1903, reprinted in MO. WEATHER REV. 31: p. 371, 1903.

[6] Angot, A.: MO. WEATHER REV. 31: 371–2.

[7] Mielke, Johannes.: Die Temperaturschwankungen, 1870-1910, in ihrem Verhältnis zu der 11-jahrigen Sonnenfleckenperiode. *Archiv der Deutschen Seewarte*, XXXVI, No. 3, 1913.

TABLE 3.—*Mean annual temperature deviations within a sun-spot cycle of 11.1 years (the mean for 1867 is combined with the preceding and succeeding years).*

[Figures without signs are plus (+).]

Years.	0	1	2	3	4	5	6	7	8	9	10
1811	1.0	−2.2	−0.4	0.0	−1.0	−1.7	−1.5	−0.6	1.0	−0.1	−0.6
1822	0.9	−0.6	0.6	2.0	1.8	0.7	2.9	−0.6	1.7	0.4	0.1
1833	0.4	0.6	−1.6	−2.6	−1.8	−1.6	0.0	0.0	−0.5	0.1	−1.2
1844	−0.2	0.3	1.3	−0.3	0.4	−0.3	0.2	0.3	0.1	0.4	1.1
1855	0.0	−1.8	−1.3	0.2	−0.3	0.6	0.4	−0.1	0.1	0.0	1.0
1867	0.3	−0.9	−0.5	1.7	0.9	−0.8	−0.5	0.6	−1.2	−0.1	0.9
1878	1.4	0.9	−0.4	0.7	0.2	−0.7	−0.5	−0.4	−0.4	0.2	−0.3
1889	0.7	0.1	−0.6	−0.9	0.1	−0.8	0.6	0.2	0.1	−0.3	1.3
1900	0.4	0.1	−0.6	−0.5	−0.4	0.4	−0.2	0.6	0.1	0.9	0.4
1911	−0.9	0.5	0.6	0.4	−0.5	−1.3	0.5	0.4	−0.3	2.4	......
Means	0.40	−0.30	−0.29	0.05	−0.06	−0.55	0.19	0.04	0.07	0.39	0.30

There is evidence in both curves of the existence of a principal and, indeed, two secondary maxima within the

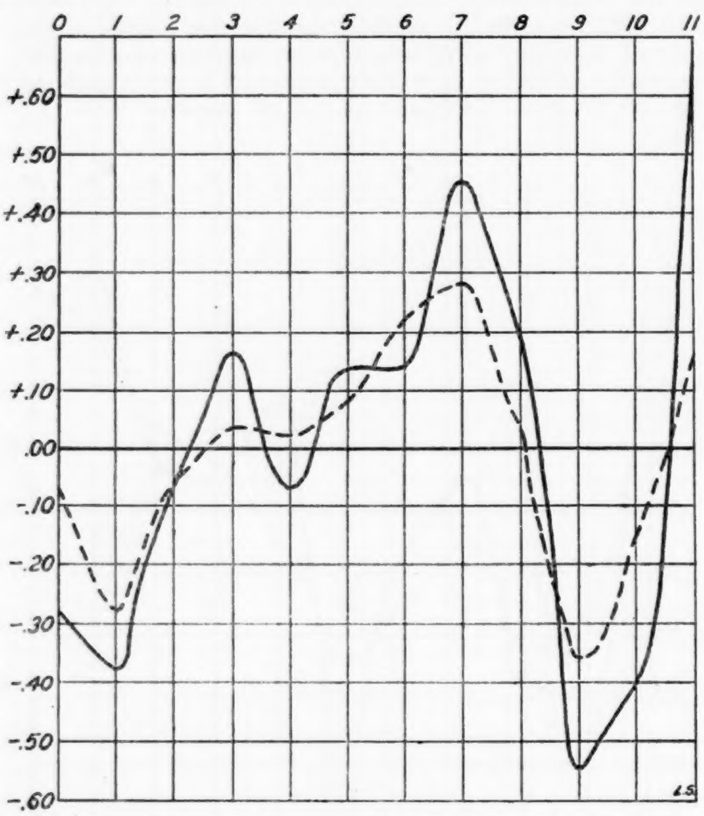

FIG. 3.—Annual deviation in a 12-year period. Full curve unsmoothed, broken curve smoothed values.

11-year cycle. The principal maximum occurs at time of spot minimum according to expectation and the principal minimum of temperature occurs 5 years after the average epoch of spot minimum. The amplitude of the fluctuations is, however, quite small, so small that in order to show it it is necessary to resort to the second decimal place in the means. When we examine the individual values in the table we are struck by the fact that the course of the mean curve is determined by one or more large individual deviations such as occurred in 1825, 1828, 1836, 1837, 1838, 1870, and 1921. The peak of the full-line curve in Figure 2 is reached solely by reason of the great positive departure of temperature for 1921. True the epoch of spot minimum is not far distant. If we combine columns zero and 10 we get 0.35 F. as an average of the heat maximum in the United States on the assumption of an 11.1-year period. This amount is just one-half of the average annual deviation, which as before stated, amounts to 0.7 F. The average of the heat minimum is 0.55 F. and we may say both results are of small significance except from an academic point of view.

As there seems to be some evidence of a 4-year period I have tabulated the figures of the above table in horizontal rows of 12 columns, since both 3 and 4 are multiples of that number.

The results of that tabulation are shown in Figure 3, where, as before, the unsmoothed means are given in the full curve and the smoothed means in the broken curve.

The full curve shows a progressive rise in temperature from zero year to column 7, thence a decline to a minimum in column 9 and a sharp rise to column 11 which corresponds to the 12th year in the series. Curiously all of the entries in that column are positive, which amounts to saying that from 1811 to 1921 the temperature every twelfth year was above the normal. On the whole the results of this tabulation are negative so far as giving evidence of the reality of any periodicity is concerned.

LARGE AREAS VERSUS SMALL AREAS.

The question has arisen is it advisable to use areas of great geographic extent only moderately well covered by observing stations, in preference to smaller areas with a

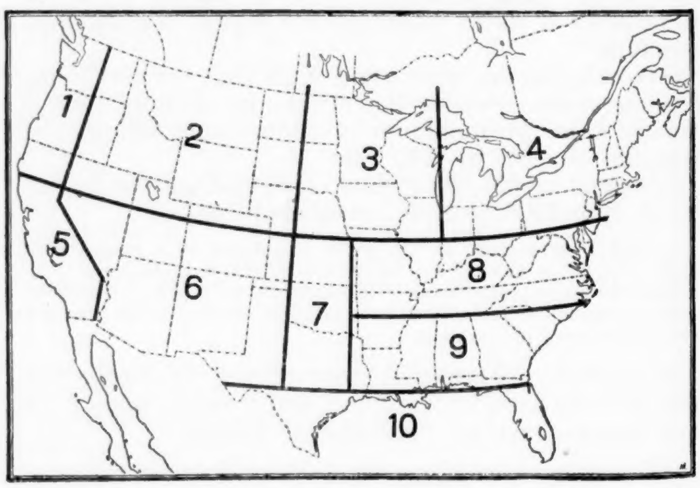

FIG. 4—Subareas in United States used in the computation.

better network of stations. To secure information upon this point I have divided the United States into 10 districts or subareas as shown in Figure 4.

The districts are numbered consecutively from west to east and from north to south. The mean deviation for each district has been computed and the numerical values appear in Table 4 and are presented graphically in Figure 4. The means are unsmoothed and may be compared with the results for the United States as a whole which appear in the curve so marked just below the curve for district No. 6. It is a matter of common knowledge that the Rockies sometimes form an approximate dividing line between regions of positive and regions of negative departures. The order of presenting the curves of Figure 5 is intended to show the deviations west of the Rockies in a group by themselves. Curve No. 1 represents the western part of Washington and Oregon, also northern California. No. 2 the northern Rocky Mountain and Plateau region; No. 5, California south of San Francisco; and No. 6, the southern Plateau and Rocky Mountain region. The effect of oceanic control is seen in districts Nos. 1 and 5.

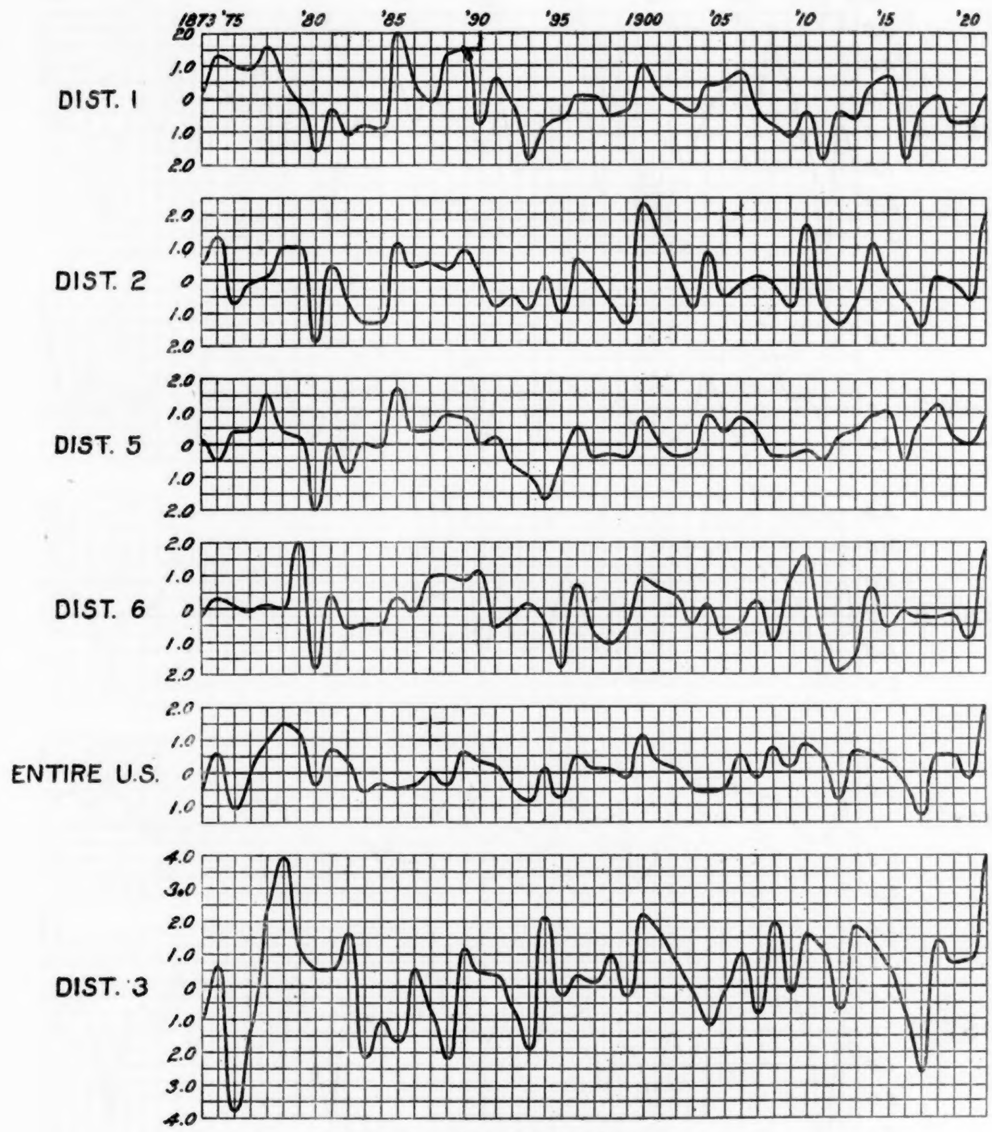

FIG. 5.—Annual deviation by subareas.

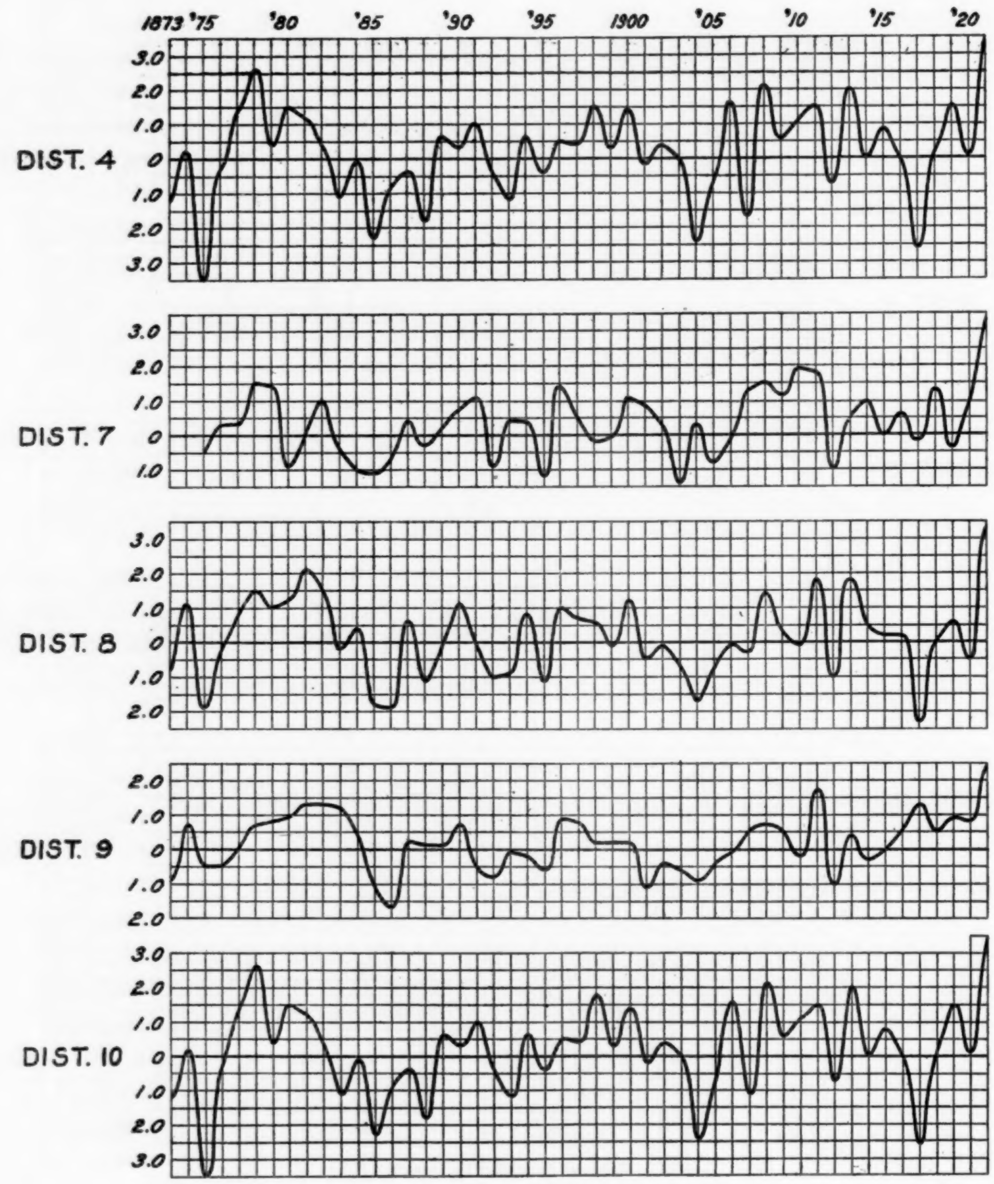

FIG. 5, Continued.—Annual deviation by subareas.

TABLE 4.—*Annual temperature deviations in United States by districts, 1873–1921 (°F.).*

Year.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.	No. 10.
1873	0.2	0.5	−1.0	−1.2	0.1	−0.2	....	−0.8	−0.9	−1.2
1874	1.3	1.3	0.6	0.2	−0.5	0.3	....	1.1	0.7	0.2
1875	1.0	−0.7	−3.8	−3.5	0.4	0.1	−0.5	−1.9	−0.5	[1] −3.5
1876	0.9	−0.1	−1.3	−0.3	0.4	−0.1	0.3	−0.3	−0.5	−0.3
1877	1.6	0.1	2.3	1.4	1.5	0.1	0.3	0.8	0.0	1.4
1878	0.7	1.0	3.9	2.6	0.4	0.0	1.5	1.5	0.7	2.6
1879	−0.1	1.0	1.1	0.4	0.2	2.0	1.4	1.0	0.8	0.4
1880	−1.6	−1.9	0.5	1.5	−2.0	−1.8	−0.9	1.2	0.9	1.5
1881	−0.3	0.4	0.5	1.2	0.0	0.4	0.0	2.1	1.3	1.2
1882	−1.1	−0.7	1.6	0.4	−0.9	−0.6	1.0	1.5	1.3	0.4
1883	−0.8	−1.3	−2.2	−1.1	0.0	−0.5	−0.4	−0.2	1.2	−1.1
1884	−0.9	−1.3	−1.1	−0.1	−0.1	−0.5	−1.0	0.4	0.4	−0.1
1885	2.0	1.1	−1.7	−2.3	1.7	0.3	−1.1	−1.8	−1.1	−2.3
1886	0.5	0.4	0.5	−0.9	0.4	−0.1	−0.7	−1.9	−1.7	−0.9
1887	−0.1	0.5	−0.8	−0.4	0.4	0.9	0.4	0.6	0.2	−0.4
1888	1.3	0.3	−2.2	−1.8	0.9	1.0	−0.3	−1.1	0.1	−1.8
1889	1.5	0.9	1.1	0.6	0.8	0.8	0.2	−0.1	0.1	0.6
1890	−0.8	0.2	0.4	0.3	0.0	1.1	0.7	1.1	0.7	0.3
1891	0.6	−0.8	0.3	1.0	0.2	−1.1	1.1	0.0	−0.5	1.0
1892	−0.1	−0.5	−0.7	−0.4	−0.7	−0.3	−0.9	−1.0	−0.8	−0.4
1893	−1.8	−0.9	−1.9	−1.2	−1.0	0.1	0.4	−0.9	−0.1	−1.2
1894	−0.9	0.1	2.1	0.6	−1.7	−0.4	0.4	0.8	−0.2	0.6
1895	−0.6	−1.0	−0.3	−0.4	−0.5	−1.8	−1.2	−1.1	−0.6	−0.4
1896	0.1	0.6	0.3	0.5	0.5	0.7	1.4	1.0	0.9	0.5
1897	0.1	0.1	0.1	0.4	−0.4	−0.7	0.5	0.7	0.8	0.4
1898	−0.5	−0.7	0.9	1.5	−0.3	−1.1	−0.2	0.6	0.2	1.5
1899	−0.4	−1.3	−0.3	0.3	−0.4	−0.6	−0.1	−0.1	0.2	0.3
1900	1.0	2.3	2.2	1.4	0.8	0.9	1.1	1.2	0.2	1.4
1901	0.2	1.4	1.6	−0.2	0.0	0.6	0.9	−0.5	−1.1	−0.2
1902	−0.1	0.2	0.7	0.4	−0.4	0.4	0.3	−0.1	−0.4	0.4
1903	−0.4	−0.8	−0.2	0.0	−0.3	−1.0	−1.4	−0.7	−0.6	0.0
1904	0.4	0.8	−1.2	−2.4	0.9	0.1	0.3	−1.7	−0.9	−2.4
1905	0.5	−0.5	−0.1	−0.7	0.4	−0.8	−0.8	−0.7	−0.4	−0.7
1906	0.8	−0.2	1.0	1.6	0.8	−0.6	−0.1	−0.1	−0.1	1.6
1907	−0.3	0.1	−0.8	−1.7	0.4	0.2	1.3	−0.3	0.5	−1.7
1908	−0.8	−0.2	1.9	2.1	−0.4	−1.0	1.5	1.4	0.7	2.1
1909	−1.2	−0.8	−0.2	0.6	−0.4	0.8	1.2	0.3	0.5	0.6
1910	−0.4	1.7	1.6	1.1	−0.2	1.6	1.9	−0.1	−0.2	1.1
1911	−1.7	−0.8	1.1	1.5	−0.5	−0.7	1.8	1.8	1.7	1.5
1912	−0.4	−1.3	−0.7	−0.7	0.2	−1.9	−1.0	−1.0	−1.0	−0.7
1913	−0.6	−0.7	1.8	2.0	0.4	−1.5	0.5	1.8	0.4	2.0
1914	0.4	1.1	1.4	0.0	0.9	0.6	1.0	0.5	−0.3	0.0
1915	0.7	0.1	0.6	0.8	1.0	−0.6	0.0	0.2	0.0	0.8
1916	−1.8	−0.7	−0.8	0.0	−0.5	−0.1	0.6	0.2	0.5	0.0
1917	−0.3	−1.4	−2.6	−2.6	0.7	−0.3	−0.2	−2.3	−1.3	−2.6
1918	0.1	0.1	1.4	0.2	1.2	−0.3	1.3	0.5	0.5	0.2
1919	−0.7	−0.1	0.7	1.5	0.3	−0.2	−0.4	1.1	0.9	1.5
1920	−0.7	−0.6	0.8	0.1	0.0	−0.9	0.1	−0.5	−0.8	0.1
1921	0.1	2.0	4.0	3.5	0.9	1.8	3.3	3.3	2.4	3.5

[1] Probably too great.

During the 48 years considered there were three each fairly well pronounced maxima and minima of temperature, respectively, viz, maximum in 1878, 1900, and 1921, and minimum in 1875, 1893, and 1917. The intervals between the maxima were 22 and 21 years, and between minima 18 and 24 years or an average of about 22 years. But even these exceptional years do not show uniform deviations in all parts of the country. In general the deviations are not uniformly in the same sense over the entire area. In many years the deviations on the Pacific coast appear to be damped by the oceanic influence and sometimes they are in the opposite sense from those east of the Rockies, as in 1880, 1885, and 1911.

The foregoing comparison while it does not yield clear cut definite results, serves to confirm the writer in the belief previously expressed,[8] viz, that while terrestrial temperature is primarily controlled by the output of solar radiation the immediate control which results in the day-to-day weather is almost wholly the result of horizontal convection or flow of air from low to higher latitudes and vice versa. In the Bjerknes terminology the continuous shifting of the polar fronts is responsible for temperature changes of much greater magnitude than any which might reasonably be attributed to changes in the intensity of solar radiation. When these changes are integrated over a longer period, say, a month or a year, the net result is often a complex, because the shifting of any series of polar fronts is rarely continuous in one and the same direction but is made up of a series of advances and retreats of unequal extent and duration. It occasionally happens that the advance of equatorial air, or, more correctly speaking, air from middle latitudes, toward the polar regions is not seriously checked for so long a period as a month. Naturally that month is unduly warm with respect to the seasonal normal and the excess warmth is reflected in the annual mean. The remainder of the year may have been close to the normal.

This warns us that the year as a time unit is too long and that the region to look for evidences of a relation between terrestrial temperature and sun-spot activity is not in that portion of the Temperate Zones which comes within the influence of moving cyclones and anticyclones but rather in the Tropics as already suggested by a number of writers.

The negative result reached in the foregoing was not unexpected; it may have been due to one or more of a number of causes which for convenience may be stated in the form of questions: (1) Do temperature observations near the surface of the earth throw any light upon the original intensity of radiation emitted by the sun? This is fundamental. (2) How shall allowance be made for lack of observations from the tropical oceans? (3) In what degree are land observations to be used as an index of the air temperature of the globe? (4) Is it a fact, as some have assumed, that an increase in the intensity of solar radiation will first warm the upper air (the stratosphere) and that the heat so communicated will later warm the lower layers of the atmosphere (the troposphere)? (5) Is the absorption of solar radiation by the earth's atmosphere so clearly understood as to permit proper allowance to be made for it? And finally (6) the evidence since 1883 seems to indicate that when a quantity of volcanic dust is shot into the very high atmosphere as in 1883, 1912, and 1903 surface cooling results. The course of the curve in Figure 1 seems to support this view and pyrheliometer observations since 1903 also lend support to it.

[8] MONTHLY WEATHER REVIEW 4. 49:67.

SOME CHARACTERISTICS OF TEXAS RAINFALL.

By I. R. TANNEHILL, Meteorologist.

[Weather Bureau Office, Galveston, Tex., June 14, 1923.]

The most convenient measure of monthly and annual intensities of precipitation is the average amount on days with 0.01 inch or more, obtained by dividing the total amount by the number of days with precipitation in measurable amounts. Such values, indicating the annual march of rain intensity at Galveston, Tex., as an average for the years 1908 to 1922, inclusive, are shown in Figure 1.

There are two rather pronounced maxima—one in May, the other in October. The minimum in July and the relatively low intensity in August are remarkable in view of the high vapor content of the atmosphere at that season. To demonstrate that this is not purely fortuitous, similar curves are shown in Figure 2, for the 15-year periods 1878 to 1892, inclusive, and 1893 to 1907, inclusive. In the curves of Figure 2, both early maxima occur in June while the autumn maxima occur in September in one average and in October in the other. The minimum occurs in July in one average and in August in the other.

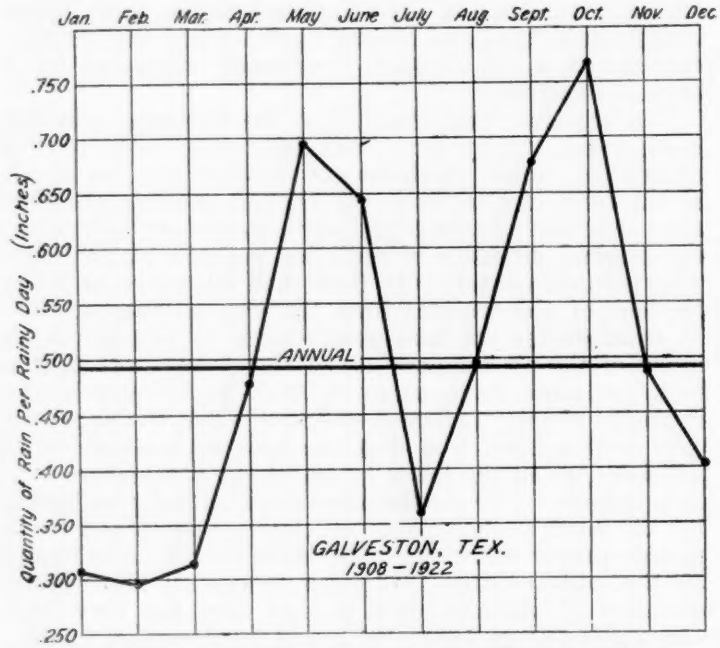

FIG. 1.—Monthly mean quantity of rain per rainy day at Galveston, Tex.

These curves indicate that the intensity of rainfall at Galveston is extraordinarily low in midsummer.

Since these curves are based upon the average quantity of rain on a rainy day, a further calculation of rain intensity has been made to determine the reliability of this measure of rain intensity.

The Weather Bureau tabulates for each month the maximum fall of rain for a five-minute period in that month. Averages of these maximum five-minute intensities for the period 1908 to 1922, inclusive, have been calculated. These are shown in Figure 3. As a further test, the number of hours during which rain fell in each month for the period 1908 to 1922, inclusive, has been determined. This is taken as the duration of rainfall for each month. The monthly rainfall amount divided by this value of duration in hours, gives a value of rain intensity per rainy hour. The resultant values are shown in Figure 3 as the average monthly rain intensity. These curves show roughly the same annual variation, with a minimum in July.

There are undoubtedly many factors influencing the intensity of rainfall. It is obvious, however, that, other factors remaining constant, the intensity of rainfall will vary directly with the temperature, which determines the maximum vapor content of the atmosphere.

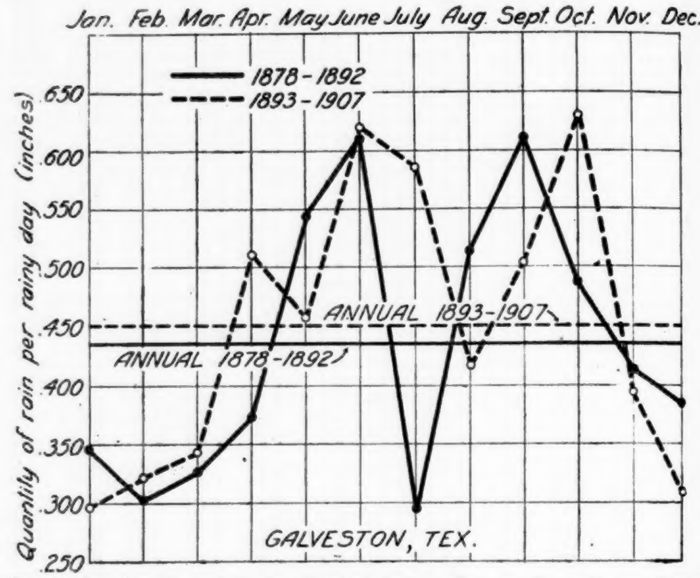

FIG. 2.—Quantity of rain per rainy day at Galveston, Tex., as shown by two 15-year periods.

To illustrate this point, see Figure 4, which shows the annual march of temperature and rain intensity at Chicago for the years 1871 to 1910, the intensities being expressed as average rainfall per rainy day.[1]

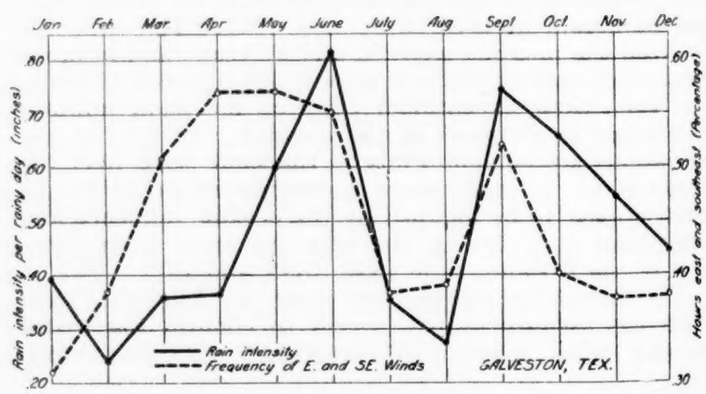

FIG. 3.—Monthly mean maximum rainfall for a 5-minute period at Galveston, Tex.

Here the intensity varies rather uniformly with the temperature, the maximum intensity occurring in July. This is in marked contrast to the distribution of intensity at Galveston. The mean annual intensity at Chicago is 0.27 inch; at Galveston, for the 45-year period, 1878 to 1922, it is 0.46 inch, nearly double that of Chicago. Yet, the mean intensity at Chicago in July is 0.37 inch and at Galveston 0.41 inch. Galveston is only slightly in excess of Chicago in July intensity. On the other hand, in June Chicago averages 0.32 inch, Galveston 0.62 inch; in October Chicago is 0.26 inch, Galveston 0.63 inch.

[1] Cox and Armington: *Weather and Climate of Chicago.*

The distributions at the two stations are strikingly dissimilar, and, while Chicago is evidently affected largely by variations in temperature and consequently in vapor content, the rain intensity at Galveston is evidently controlled by some other pronounced influence, which affects the distribution of moisture over the State and its availability as rainfall.

The distribution of rainfall intensity, characteristic of Galveston, is reflected in the rainfall curves for a considerable portion of the State of Texas and adjoining sections. A number of these diagrams are shown in Figure 5. These curves are based upon station annual summaries, and while the period of observation varies with the station, the tendency toward a maximum rainfall in May to June and again in September, with a secondary minimum in July or August, is quite apparent, thus indicating the influence of increased rain intensity at those periods in spring or early summer and in the autumn. It is true that the quantity of rain is the product of frequency by intensity, but these increased rainfall yields are due to intensity and not to frequency, as an examination of records of number of rainy days will indicate. In Table 1, the frequency of rainy days at Galveston, 1878 to 1922, inclusive, is shown. Though the June rainfall exceeds that of July, the number of rainy days in July is considerably in excess of that in June.

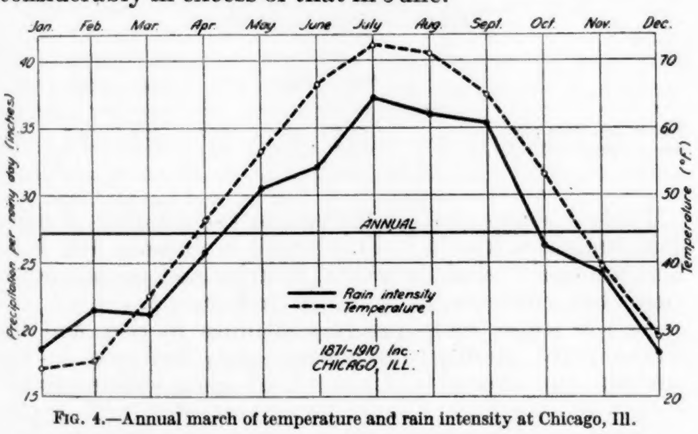

FIG. 4.—Annual march of temperature and rain intensity at Chicago, Ill.

The Gulf of Mexico is undoubtedly the chief source of moisture for this region. The frequency, velocity, and direction of the moisture-bearing winds determine the characteristics of its rainfall.

TABLE 1.—*Average number of days with 0.01 or more precipitation at Galveston, Tex., period 1878 to 1922, inclusive.*

January	10.2
February	9.2
March	8.1
April	6.7
May	6.2
June	6.9
July	9.0
August	9.5
September	9.3
October	7.0
November	7.8
December	9.8

The annual variation in frequency of east and southeast winds at Galveston, Tex., is shown in Figure 6. The percentage of total hours each month in which the wind blew from east and southeast, for the five years, 1918 to 1922, inclusive, are shown, together with the average rain intensities for the same period.

It will be evident from a study of this figure that there is a well-defined relationship between frequency of these winds and the intensity of rainfall, bearing in mind, however, that temperature also affects rainfall intensity. The prevailing southeasterly wind over Texas is in the nature of a monsoon, and its advance and retreat in May to June and September to October, respectively, are attended by increased intensity of rainfall, undoubtedly because of the attendant shift in wind direction.

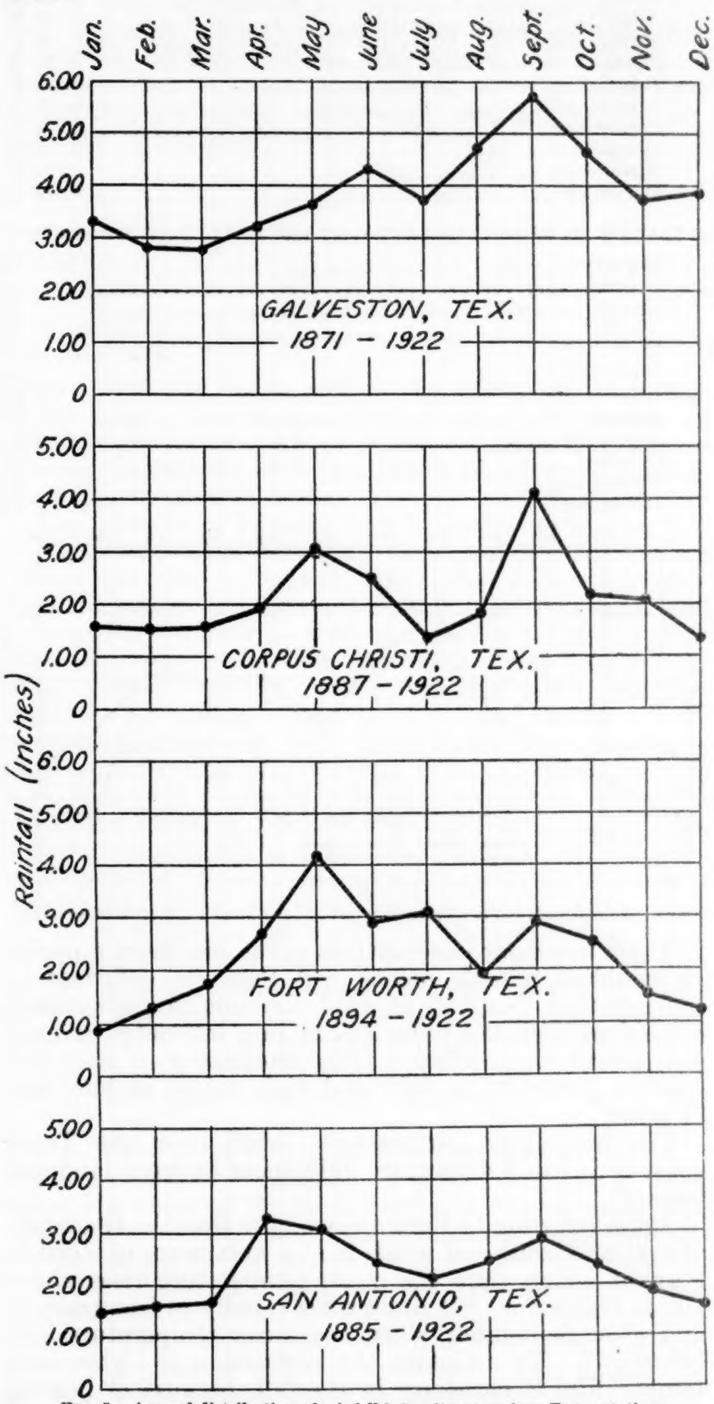

FIG. 5.—Annual distribution of rainfall intensity at various Texas stations.

This backing of the wind to easterly in the late spring and early fall, extends to considerable heights above the earth's surface.

Table 2 shows the average wind directions and humidity percentages at 1,000 meters over Groesbeck, Tex., during the period October, 1918, to December, 1920. Note that the movement has a westerly component in all months except June and September, when it shifts to easterly.[2]

[2] Gregg, Willis R.: An Aerological Survey of the United States. MO. WEATHER REV. SUPPLEMENT NO. 20.

TABLE 2.—*Based on 670 observations at Groesbeck, Tex., at altitude of 1,000 meters, October, 1918, to December, 1920, station altitude 141 meters.*

WIND DIRECTION AT 1,000 METERS AT GROESBECK, TEX.:

January	N. 65 W.
February	S. 79 W.
March	S. 26 W.
April	S. 28 W.
May	S. 23 W.
June	S. 14 E.
July	S. 32 W.
August	S. 28 W.
September	S. 4 E.
October	S. 5 W.
November	S. 71 W.
December	S. 50 W.

RELATIVE HUMIDITY, PER CENT, AT 1,000 METERS AT GROESBECK:

January	65
February	60
March	53
April	59
May	72
June	69
July	68
August	74
September	71
October	78
November	61
December	54

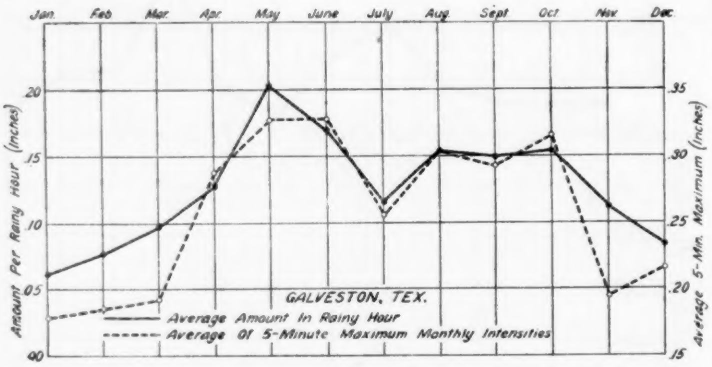

FIG. 6.—Annual variation in frequency of east and southeast winds at Galveston, Tex.

These upper-air observations cover too short a period to establish reliable means, yet they are sufficient to indicate that this shift of wind direction in midsummer, coincident with the reduction in rain intensity, extends well above the surface. It is interesting to note low relative humidity in July and high values in May and October.

The prevailing southeasterly wind over the Texas coast is due to temperature differences between land and water.[3]

Again referring to Figure 6, we note that the frequency of east and southeast winds is at a maximum in April to May, at which time the mean temperature rises above 70° at Galveston. It diminishes rapidly in frequency in and after September, when the mean temperature falls below 75°. To maintain the circulation, a higher land temperature is necessary in the fall, because of heating of the water surface during the summer months. It will be noted from a study of the upper-air observations that the wind becomes south-southwest in midsummer at 1,000 meters, while at the surface the wind is apt to prevail from the south.

These shifts in direction of the monsoon-like wind are due to migration and expansion of the area of maximum heat in the interior. In midsummer the heated area extends northward and the monsoon veers to the south. Table 3 gives the mean temperature at Forth Worth and at San Antonio for the months May to October. The higher temperature in each month is *in italics*. It will be seen that in the months of May and June and again in September and October, San Antonio has a higher mean temperature than Forth Worth, indicating that the stronger temperature gradient lies toward the west, hence the strong easterly component in the wind movement.

In July and August, particularly the former, it is warmer at Fort Worth, indicating that the stronger gradient now lies to the northward giving rise to southerly winds at the surface. There is a south-southwest wind aloft with lower relative humidity. It appears that in midsummer the heated area has expanded, covering a vast area of the Middle West and Southwest, and that a gradient is established from the water surfaces of the Gulf and Pacific toward this vast heated interior. This is in contrast to the earlier and later terms during which the local area of heat in the Southwest establishes a temperature gradient toward the Gulf.

This midsummer southerly wind moves more slowly, due to less pronounced temperature gradients. Its slower movement is more favorable for convection and rainfall occurs with greater frequency, though with less intensity.[4]

TABLE 3.—*Mean temperatures.*

	May.	June.	July.	Aug.	Sept.	Oct.
Fort Worth (1894–1922)	73.2	80.1	*83.7*	*82.9*	76.7	66.3
San Antonio (1885–1922)	*74.8*	*80.4*	82.4	82.0	*77.1*	*69.2*

Table 1 shows that at Galveston the number of rainy days increases from 6 in May and 7 in June to 9 in July. The southerly wind, however, is drier and consequently yields less moisture, as is shown in Figure 5.

As the water temperature continues to rise, and the temperature gradient is consequently reduced in the autumn, the area of maximum heat again shifting to the southwest, we find a slow moving current with a pronounced easterly component in September, lingering into October, at which season the rainfall over southern Texas is at maximum frequency and intensity, as evidenced by the September rainfall at Corpus Christi, Brownsville, and San Antonio.

In conclusion, the movement of rain-bearing winds and resultant distribution of rainfall over Texas have the following characteristics:

(1) In spring a strong southeasterly wind blowing into the heated southwest from a relatively cool water surface; winds sufficiently strong at frequent intervals to suppress convection over the southern portion of the State; moisture content high and rainfall intense when it does occur.

(2) Slower wind movement more favorable for convection over the northern portion of the State; high vapor content and period of maximum rains in the north.

(3) Slower movement from south in midsummer, as air drains toward heated portion of north Texas and adjoining districts; increased rain frequency near the source of moisture but prevailing wind drier, yielding less intense rainfall.

(4) Southeasterly winds again setting in with autumn, blowing into area of maximum heat in southwest, but with higher water temperature and consequent slower

[3] McAuliffe, J. P.: Cause of the accelerated sea-breeze over Corpus Christi, Tex. Mo. WEATHER REV., Nov., 1922, 50: 581–582.

[4] Tannehill, I. R.: Wind velocity and rain frequency on the South Texas Coast, Mo. WEATHER REV., September, 1921, 49: 498–499.

wind movement favorable for greater rain frequency; high vapor content favorable for increased rain intensity. When these conditions occur, the record-breaking rains of southern Texas are sometimes recorded. This condition is favorable for the development and movement of cyclonic disturbances from east to west and intense rainfall results.

We find then that conditions favorable for rainfall distribution of certain characteristics become established over this region and persist for considerable periods. These conditions do not return each year at the same time; for example, the midsummer condition sets in earlier in some years than others; the spring and autumn conditions shift considerably from year to year.

The solution is found in the distribution of temperature over land and water surfaces. That any given condition has become established will be apparent from the wind movement at the surface and aloft. With the knowledge that such a condition has become established, the general characteristics of the rainfall over this region should then be forecast as regards frequency, quantity, and intensity. Further upper air observations, disclosing the structure of the atmosphere over this region for a number of years, thus giving more reliable data concerning prevailing winds aloft, average movements, etc., will undoubtedly assist.

PANAMA CLIMATE.[1]

By R. Z. KIRKPATRICK,
Chief Hydrographer, The Panama Canal.

[Balboa Heights, Canal Zone, May 4, 1923.]

Panama lies wholly in the Torrid Zone and is very close to the thermal equator. Its climate may be characterized as warm, humid, and equable. The year is divided into a dry season of four months' duration, January to April, inclusive, and eight months' wet season.

The climate of Panama is approximately that of July in the North Atlantic States from Virginia to New Hampshire, except that during the rainy season it has more rain and humidity. The mornings are bright and fresh, the days warm, the evenings refreshing, and the nights gloriously clear; one sleeps under at least one sheet. In the high lands of the Province of Chiriqui temperatures run down to as low as 50° F. at night.

An American in Panama is often amused at his mail from the United States, written during a sweltering July or August with 95° to 105° F. temperature. His friend will write of the local torridity, the hot nights and their discomfort, and ends up with a sympathetic, "I do not see how you stand it down there."

Taking the month of July as the criterion for a warm month (and remembering that Panama's monthly average temperatures vary but slightly), the following table is a comparison for cities of the United States selected at random:

Stations.	Mean July temperature.	Record temperatures any month.		Mean annual relative humidity.	Mean annual rainfall.
		Highest.	Lowest.		
Mobile	80	102	−1	79	62.0
Denver	72	105	−29	52	14.0
Washington	77	106	−15	72	43.5
Key West	84	100	41	78	38.7
Chicago	72	103	−23	74	33.3
New York	74	100	−13	72	44.6
New Orleans	81	102	7	78	57.4
St. Louis	79	107	−22	70	37.2
Boston	71	104	−14	72	43.4
San Francisco	57	101	29	80	22.3
Oklahoma	80	108	−17	70	31.7
Charleston, S. C	81	104	7	78	52.1
Galveston	83	99	8	81	47.1
Norfolk	78	102	2	....	49.5
Colon, Panama	80	93	66	84	127.8
Balboa Heights, Canal Zone	80	97	63	83	69.4

The lines of demarcation between the dry and wet seasons are neither constant nor always clearly marked. Occasionally the dry season begins as early as the 1st of December, while in other years rainy weather continues into January. Usually the rains cease in mid-December and begin again about April 20.

During the rainy season it does not rain all the time, usually not more than one or two hours of the 24. As spread over the season, rain falls about one-twentieth of the time. This is equivalent to about 40 minutes of the daylight hours. About 20 days in each month have one-one hundredth of an inch or more of precipitation; the other 10 days have less.

The Isthmus of Panama is so located that the convectional influences are very great; cyclonic disturbances are almost unknown. The Isthmian currents, due to convection of heat, are nearly vertical, and moisture evaporated in a region exposed to these currents is largely precipitated before being carried very far. The slopes of Panama's hills and mountains also obstruct and deflect upward the prevailing winds, which tends to make a well-watered country and perennial streams. So effective is this cause in producing rainfall, it is not exceptional to find luxuriant vegetation on the windward side of a mountain range, whereas the leeward side is dry, with sparse growth. While this is not true to any considerable extent in Panama, it is a fact that the rainfall varies from the Atlantic coast with its 130 inches of annual rainfall to 70 inches on the Pacific, on the average.

Long-continued rainstorms, extending over a large area are of infrequent occurrence. Rainfall is usually in the form of showers of limited areas and is influenced by topography. Storms giving a greater precipitation than 6 inches on the Atlantic side or 4.5 inches on the Pacific are of infrequent occurrence. Exceedingly heavy falls of rain occasionally occur, however. One record from Porto Bello, 2.46 inches in five minutes, stands as a world's record.[2] In regions of steep topography such rains are followed by flashy flows in the streams that make travel in the interior very difficult and even dangerous during the wet season.

Most of Panama's streams are good water producers, but either go dry or have very small flows during the dry season. The interior roads and trails are usually in bad condition, due to lack of attention. The paucity of bridges, with the consequent necessity of fording streams, tends to accentuate unduly in the traveler's mind the inherent difficulties of travel in the interior.

Winds, especially along the Atlantic coast, show marked variations between the dry and rainy seasons. During the dry season months, fresh northerly trade winds prevail, coming from the north and northeast 90 per cent of the time, with an average velocity of about 15 miles per hour. During the wet season there is considerable wind from the south and southeast, particularly on the Atlantic side.

[1] A report prepared for the Panama Commercial Association.

[2] Cf. MO. WEATHER REV., May, 1920, 48: 274-276.

The average hourly velocity is highest near the hours of maximum temperatures, i. e., from 10 a. m. to 3 a. m. and lowest near the hours of minimum temperatures, 5 to 7 a. m. Calms are common in the early morinng.

As a rule, the maximum wind velocities occur during rain or thunder squalls. These storms are almost invariably too short to cause dangerously rough seas, although at times they do blow down trees and damage plantations set to bananas or other fruit. The Isthmus, fortunately, is at least 200 miles west of the path of the West Indian hurricanes. Occasional dry-season "northers" give general winds from the north, averaging up to 30 miles an hour. The greatest velocity recorded since American occupation was in a local storm at Ancon, Canal Zone, when the wind went up to 59 miles an hour.

The Isthmus has little fog, but occasionally one sees a dense fog bank hanging over a low-lying valley in the night or early morning in the interior, particularly in the wet season. Practically all fogs are dissipated by 8:30 a. m.

Daytime cloudiness is less in the dry season. March has the least cloudiness; June and November the most. Due to prevailing wind direction, there is more cloudiness in the interior and on the Pacific coast. These winds reach the Isthmus from the Carribean with water vapor in large measure uncondensed, and therefore are not visible as clouds. As they cross the Isthmus, this vapor is partly condensed and becomes visible as a cloud.

Cloudiness is generally greater in the daytime than at night. This is especially noticeable during the dry season, when heavy cumulus clouds form during the day and as regularly disappear with the approach of night.

Humidity is the feature of Isthmian climate that makes many days decidedly "sticky." In the dry season it is not so bad. The change of season from dry to wet is particularly oppressive, owing to low wind movement and high humidity. It is necessary to maintain "dry" closets—a small closed room containing a lighted lamp—to prevent molding of clothing and shoes. Bedding must be aired and renovated frequently.

CONCERNING HALOS OF ABNORMAL RADII.[1]

LOUIS BESSON.

[Paris, France, May 3, 1923.]

The theory of halos of abnormal radii recently explained by Dr. W. J. Humphreys[2] is not as new as he thinks. Three years ago,[3] I showed how one can explain all these halos by means of a single ice crystal with oblique faces, except that I assigned to these faces an inclination of 25° 14′ to the principal axis, instead of 24° 51′ given by Doctor Humphreys.

I hope I may be permitted to return to this debatable question of meteorological optics in which X-rays are called into testimony in a manner equally curious and unexpected.

In my work of 1920, I gave a list of 26 observations of one or more halos of radius different from 22°, 46°, and 90° which had come to my attention. From the examination of these observations, I concluded that "of these extraordinary halos, the less rare and better determined are the halo of van Buijsen (8° 30′), that of Rankin (17° 30′), that of Burney (19°), and that of Scheiner (28°). There exist one or two others—that of Dutheil (24°) and an ill-defined halo of 32° or 35°, that of Feuilleé."

Authors have been in accord, since Bravais, in explaining these phenomena by means of oblique faces of crystals of atmospheric ice, assuming the different possible known inclinations. Following an inverse process, I have sought to deduce from the radii of the observed halos the inclination of the faces.

"The halos which furnished the most reliable basis for this research were," I said, "that of van Buijsen, of Rankin, and of Burney. These are the most frequent and there is an evident relation between them since they appear together; they ought, reasonably, to be the products of the same ice crystal."

For the study of this question, it is convenient to calculate, for a certain number of values of the inclination between 0° and 90°, the radii of all the halos which the complete form can produce and to make a graph showing how the radii vary with respect to the inclination, and which are the halos that correspond to given inclinations. On the graph, one sees immediately that there are only two inclinations which can possibly furnish at one time the three halos of 8° 30′, 17° 30′, and 19°. One of these is in the neighborhood of 25° and the other is near 28°. I have remarked that these two inclinations give not only these three halos but also those of Feuilleé and Dutheil—that is to say, five of the six known extraordinary halos.

The inclination in the vicinity of 25° is in better accord with the observations of halos and it is also in harmony with the value 54° 44′ which Bravais has given of a crystallographic observation of Clarke, which is

$$3 \tan 25° \, 14.4' = \tan 54° \, 44.1',$$

and this has led me finally to maintain as particularly probable, the value 25° 14.4′.

I reproduce below an extract of a table from my note of 1920, introducing, for the reader's convenience, the notation employed by Doctor Humphreys to designate the faces of the crystal.

TABLE 1.—*Dihedral angles in an hexagonal prism with oblique faces inclined 25° 14.4′ to the principal axis and the radii of halos produced by them.*

Faces of incidence and emergence.	Dihedral angle.		Radius of halo.		Name of halo.
	°	′	°	′	
p_1, p_4	50	28.8	17	26	Rankin.
p_1, p_3	76	51.8	32	10	Feuilleé.
c, p'_1	64	45.6	24	21	Dutheil.
m_1, p_4	25	14.4	8	2	van Buijsen.
m_1, p_3	63	6.6	23	27	Dutheil.
p_1, p'_6	53	46.8	18	53	Burney.

Halos of van Buijsen, Rankin, and Burney.—In order to know as closely as possible the real values of the radii of these halos, we return to those observations made most recently and retain only those in which at least two of the three were seen together. This is to eliminate the cases of halos of nearly the same radii which could be produced in another way. These observations to the number of seven are as follows:

[1] Translated by C. LeRoy Meisinger.
[2] MO. WEATHER REV., October, 1922, 50: 535-536.
[3] *Comptes Rendus de l'Academie des Sciences*, pp. 334 and 607, 1920.

TABLE 2.—*Observations of halos of abnormal radii.*

Observer and date.	Halo of—		
	van Buijsen.	Rankin.	Burney.
	°	°	°
Hissink, 1899	7.5	17.5	19.5
Hissink, 1899	9.0	....	19.0
Hissink, 1905	....	18.0	19.5
Besson and Dutheil, 1911	9.0	[1] 18.5	....
Andrus and Riley, 1915	8.5	17.5	18.5
Brush, 1919	7.0	17.0	19.0
Grundmann, 1922	9.0	17.0	19.0
Mean	8.3	17.4	19.0
Theoretical value with inclination 25° 14.4′	8.0	17.4	18.9
Theoretical value with inclination 24° 51′	7.9	17.1	19.0

[1] This halo could be classed almost as well as the halo of Burney.

The values of the radii deduced from an inclination of 24° 51′ clearly show a larger departure from the observed value. Further, for the halos of van Buijsen and Rankin, the radius varies very rapidly with inclination, the sign of the departure being precisely that which results from too small a value of the inclination. The experimental results upon which the value of 24° 51′ is based not being more than approximate, I do not see a decisive reason for rejecting the value of 25° 14.4′.

Halo of Dutheil.—A halo of 24° was very clearly seen by Dutheil in 1911 of which the radius was measured.[4] One can explain this by refraction either between the base *c* of the crystal and an oblique face at the other end, or between a prismatic and an oblique face. If these crystals are prisms terminated at both ends by non-truncated pyramids, only the second mode of production is possible; but if these crystals are simple or double pyramids, without prismatic section, it is, on the contrary, only the first mode that is possible.

Halo of Scheiner.—It does not appear possible to admit with Doctor Humphreys that the halo of Scheiner and the halo of Feuilleé constitute one and the same phenomenon. There are six observations of the halo of Scheiner; three very old ones—those by Scheiner (25° to 28°), Greshow (26°), and Whiston (29°), which I cite from Bravais; and three recent ones—those by Besson (28°), Andrus and Riley (28° to 29°), and Noyer[5] (28°). These observations assign a value of the radius in the neighborhood of 28°.[6]

[4] Annales de l'Observatoire de Montsouris. 12: 236.

When one passes in review the halos which can be produced by crystals whose oblique faces are inclined either by 19° 28′ (inclination which X-rays seem to designate as corresponding to the prismatic form of ice) or by an angle of which the tangent is in simple relation with tan 19° 28.2′, one perceives that a very large number of these halos have a radius little different from 28°.

Calling x the inclination and placing

$$K=\frac{\tan x}{\tan 19° 28.2'},$$

we find that for values of K smaller than unity that there are no halos of the required size produced; but, if K is given the values 1, 2, 3, or 4, one finds not less than seven. These are enumerated in the following table:

TABLE 3.—*Different methods of possible formation of the halo of Scheiner.*

	K	x		Faces of incidence and emergence.	Radius of halo.	
		°	′		°	′
No. 1	1	19	28.2	p_1, p_3	27	45
No. 2	1	19	28.2	c, p'	27	45
No. 3	2	35	15.9	p_1, p_4	27	45
No. 4	3	46	41.2	m_1, p_3	27	23
No. 5	3	46	41.2	p_1, p'_6	29	18
No. 6	4	54	44.1	p_1, p'_4	27	45
No. 7	4	54	44.1	m_1, p_3	29	32

The halo of Scheiner which I have observed was reduced at its highest point. For that reason it can not be attributed very satisfactorily to mode of formation No. 2, but clearly does not prove that this halo is not produced in that manner. In whatever manner, the most probable value of its radius appears to be 27° 45′.

[5] Annales des Services techniques d'Hygiène de la Ville de Paris. 2: 269, 1920.
[6] I do not believe the error can exceed 1°.

COMMENTS ON HALOS OF UNUSUAL RADII.

By W. J. Humphreys.

[Weather Bureau, Washington, D. C., June 1, 1923.]

Unfortunately Besson's article on the extraordinary halos[1] had not come to my attention when I wrote the paper he refers to above. Nevertheless, the two papers are entirely different in their lines of approach, and essentially supplementary each to the other—certainly in no sense antagonistic.

Besson's method of computing the inclination of the pyramidal faces of the snow crystal to the principal axis from the radii of the unusual halos is logical, but as these radii are known to only a rough approximation any value computed from them must also be correspondingly unreliable. I tried at first the same method and found 25° to be about right, but did not adopt it because, if the generally accepted goniometric measurements of the pyramidal ice crystal are correct, this value is crystallographically impossible.

But Dobrowolski had shown that none of these goniometric values was at all reliable, and so Besson's method of computing the angle from the radii of the halos again seemed both allowable and desirable. Then came the X-ray determinations of the axial ratio, 1.62, of the ice crystal, a ratio that permits the angle in question to be 24° 51′, which value therefore was adopted.

The computed radii of the unusual halos, that such snow crystals would give, for a point source of yellow light (refractive index, 1.31) and the correspondingly measured radii are listed in the accompanying table:

Computed.		Measured.	
°	′	°	′
7	54	8	12
17	06	17	±
18	58	19	±
23	24	23	20
24	34	......	
31	49	32	00
89	28	......	

The measurements are very unsatisfactory, because, so far as I know, two of these halos have never been instrumentally measured at all, and the others but once each, and because it is not certain to what refractive index (color, or portion of the halo) each measurement corresponds.

[1] *Comptes Rendus*, 170: 334, 1920.

The values 8° 12′ and 32°00′ were obtained with theodolites; 17° ± and 19° ± with an improvised plane-table device; and 23°20′ by measurements on the image of the halo in a basin of mercury. In this last case the reported value is 23°57′, but this reduces to 23°20′ on applying to it the same correction that must be applied to the simultaneously made measurements on the 22° halo.

In short, then, Besson computes the shape of the ice crystal from the radii of the halos; I take crystallographically possible crystals as determined from highly accurate X-ray measurements, and from among them find one that alone accounts, to well within errors of measurement, for seven, that is all, or, at least, all but one, of the recognized halos of unusual radii.

If that remaining unusual halo, of radius 28°, roughly, does exist, presumably it is formed in the manner suggested by Besson, but then it should be accompanied by a group of other halos, none of which, apparently, has ever been reported.

But whether this particular halo exists or not there is a great number of others that certainly do, and together they afford endless opportunities for observation and numerous interesting problems for the mathematical physicist, lines of work, both of them, in which Besson has long been a master.

WINDS AND WEATHER OF CENTRAL GREENLAND: METEOROLOGICAL RESULTS OF THE SWISS GREENLAND EXPEDITION.[1]

By CHARLES F. BROOKS.

[Clark University, Worcester, Mass., May 15, 1923.]

In the summer of 1912, Dr. Alfred de Quervain with three others crossed the south central part of Greenland from Jakobshavn to Angmagsalik, while another party headed by Dr. P. L. Mercanton made meteorological and glaciological observations along the west front of the inland ice near Jakobshavn. During the following winter, Dr. W. Jost and Dr. A. Stolberg made aerological observations at Godhavn, on the south coast of Disco Island. The meteorological results obtained by these three sections of the expedition will be discussed in succession.

I. SUMMER WEATHER ON THE ICE SHEET.

The ice sheet is a giant cooler projecting southward into the realm of a relatively warm ocean and spreading northward into the paleocrystic ice of the Arctic Ocean. Over such a cooler the air is continually shrinking, and, becoming heavier, it tends to slide off the ice. The prevalence of down-slope winds, even in midsummer, was strikingly in accordance with Hobbs' theory of the glacial anticyclone.[2] Under ordinary conditions, however, this would have been less marked, for there was a preponderance of general gradients westward across southern Greenland during the ascent, and eastward ones during the descent. No observations showed that a low-pressure area ever crossed the inland ice north of de Quervain's route. Some secondaries, however, passed across the southern tip. The cyclones on the west coast went north, just as those of the United States and Europe go east or northeast, and showed the characteristic barrier effect of the cold (NW.) wind in the left front quadrant, to the warm (SE.) wind (off the inland ice) in the right front quadrant. Strange though it may seem, the ice cap supplied the warm element of the cyclone under these conditions, when the air was drawn all the way across Greenland precipitating snow and liberating latent heat on the east slope and warming by compression on descending the west slope.

It was not to be expected that the temperatures over the inland ice would rise more than a degree or two above freezing, except under föhn conditions, when the wind is blowing right across Greenland. Nor was it thought that temperatures would fall much below freezing except over the surface where there was no wet snow or standing water to supply latent heat of fusion while the sun was lowest in the sky. Thus, it is not surprising to learn that the average temperature was 30.7° F. during the first 13 days the party was on the ice in the zone where melting was in progress, and that the departures of individual days amounted to only 2° to 4° F. notwithstanding a range of altitude from 550 to 1,900 meters above sea level. "On July 3 at 1,936 m., we suddenly entered a cold region," says de Quervain, to cross which required 13 days, as it extended 280 kilometers over the divide and down to an altitude of 2,250 m. on the east slope. The mean temperature of this zone was 14° F., and the means of the individual days were generally not more than 3° from this. The highest temperature was 25° and the lowest temperature, −7° F. For the last 5 days of the journey, in the eastern zone of melting, the mean was −0.02° C. (31.96° F.).

Since the sun remained above the horizon continuously during most of the crossing, the highest and lowest temperatures occurred just 12 hours apart, between 2 and 2½ hours after noon and midnight, respectively. The temperature of June 23–24 is described as characteristic of that of the border zone. The minimum, 23° F., came after 1:30 a. m. (the sun did not set) and the maximum, 35° F., between 2 and 3 p. m. Direct solar heating and perhaps also compression of descending air served to raise the air temperature above that of the ice. In the central zone, it seems likely that temperatures fall to −25° C. (−13° F.) in midsummer, and that the maximum daily range is 25° or 30° F. On cloudy days the mean range was 6.1°, on partly cloudy 9.5°, and on clear days 14.9° F. As the range in temperature is restricted where thawing and freezing alternate, it must be less in summer than at other seasons. Thus, in August and September, Nansen found daily ranges of temperature appreciably larger than those encountered by de Quervain. With continuous darkness in winter the range must be less than in autumn or spring. The rapidity with which the summer temperatures must plunge into the unknown cold of winter is shown by the contrast between the mean of all de Quervain's observations on the crossing, 23.9° F. (June–July), and Nansen's corresponding figure, 11.7° F. (August–September).

TEMPERATURES AND WINDS.

On the cold, sloping surface of the inland ice, which is smoother even than the waved surface of the ocean, it is not surprising that the air was usually smoothly flowing down the slope. Only at 6 of the 200 observations were there calms. At times the wind blew so hard that a man on skis, with two poles to push with, could not make

[1] Alfred de Quervain, P. L. Mercanton, and others: Ergebnisse der Schweizerischen Grönland expedition, 1912–1913. *Denkschr. der Schweizerischen Naturforschenden Gesellschaft.* Bd. 53. Zurich, 1920, 402 pp., maps, diagr.

[2] W. H. Hobbs: The rôle of the glacial anticyclone in the air circulation of the globe. *Proc. of the Am. Phil. Soc.*, Aug., 1915, 44: 185–225, 11 figs. Reviewed in *Bull. Am. Geog. Soc.*, Dec., 1915, 47: 963.

progress (maximum wind velocity about 20 m./s.). One day in five on the average was stormy (wind over 10 m./s.). It is well known that the speed at which cold air will descend to displace lighter, warm air depends largely on the difference in temperature. When the difference in about 100 meters of altitude exceeds 1° C. descending air will continue to be colder than the air it displaces, for on descent the adiabatic heating of air by compression is about 1° C. per 100 meters. At the edge of the ice sheet the temperature gradient always considerably exceeded the adiabatic, as it ranged from a minimum of 1.6 to a maximum of 5.5° C. per 100 meters in the course of the day. Therefore the wind off the ice continued throughout the 24 hours. The velocity, however, did go through a diurnal cycle corresponding to the changes in the temperature gradient, with a maximum averaging 5.3 m./s. at 5 a. m. and a minimum of 4.1 m./s. at 5 p. m. Upon the ice the times of maximum and minimum became later and the extremes greater, becoming 7.6 m./s. at 9 a. m. and 1 m. s. at 9 p. m. in the inner zone. Evidently the greater speed to be expected where the air is thinner is just balanced by the tendency to lesser speed in the interior, owing to smaller slope and greater distance from the marginal heated area. The broad, central zone in which melting never takes place supplies the flow of cold air down both slopes. This is continuous to the margins, but it does not reach across the bare strip on the west to Jakobshavn. The expansion of the air over the heated, rocky foreland is insufficient to do more than stop the outflow of cold air.

In clear, quiet weather wind direction is as steady as the velocity, hour after hour and day after day. On the west border of the ice the wind was SE. at 51 per cent of the observations and on the west slope from that direction 34 per cent of the times. On the southeast slope the wind direction was directly down grade, but on the west it averaged 55° to the right of the direction of the slope. Part of this difference was owing to the deflective effect of the earth's rotation over the long, westward slope, and partly owing to the position of the Baffin Bay low-pressure area. There was no evidence of a diurnal period of wind direction, except on the 5th and 6th of July, when the wind shifted at noon to S. and SW. from SE. On these days there must have been an unusual amount of expansion over the heated zone, the overflow from which impinged on the upper part of the ice slope. The wind at the edge of the ice sheet, however, remained SE. at noon on these days. A most interesting vegetational effect of the constancy of the direction from which strong, though exceedingly dry, föhn-storm winds came was seen on a delta at the northern end of the Hundebucht (E. Greenland). Stretching like a snowdrift in the shelter of each of a number of stones was a line of vegetation many meters long.

On account of the constantly windy conditions, the air temperature follows closely that of the snow surface. The snow rises to the air temperature at about 4 a. m. and gets 4° or 5° F. above it by noon (one case), then sinks very rapidly, going below the air temperature at 3 or 4 p. m. At 6 the snow is already nearly 2° colder than the air, but the depression becomes no greater. The average difference of but 2° F. is to be compared with an average difference of 9° to 10° on clear summer nights at corresponding heights in the Alps.

THE FÖHN, OR WARM WIND, OFF THE ICE SHEET.

While usually the descending air lost an appreciable degree of its compressional rise in temperature to the cold snow surface, on occasions when a general wind blew right across the ice cap (total föhn) the volumes of air and the velocities involved prevented the local cooling from becoming appreciable. Then the slope up which the wind was blowing became cloudy, and snow was precipitated as expansion cooled the rising air. The latent heat from such precipitation preventing the attainment of the adiabatic rate of cooling, the air reached the crest at a moderate temperature and on descending warmed rapidly to a high degree. Such was the case when with a gale off the inland ice the air temperature rose to 61° F. at sea level on the east coast, July 23. The air as it comes over the crest has left in it the maximum amount of water vapor possible at the temperature and pressure. If, then, the absolute humidity and temperature of the warm wind are determined as it reaches the coast, it becomes possible to find from what altitude the wind descended. On three occasions at Jakobshavn the heights indicated were 2,250, 2,400, and 2,350 meters in directions to the south of de Quervain's route, where de Quervain's observations of slope indicate a probable height of 2,400 meters on the crest over which the winds came. De Quervain says: "Whoever wishes to know the height of the middle Greenland inland ice, needs only to read the psychrometer on a true föhn day * * * and compute the rest."

HUMIDITY AND EVAPORATION.

With air temperature and snow temperature about the same and with the snow constantly evaporating the relative humidity was necessarily high, averaging 82 per cent, and, in general, varied but little. On comparing the snow-surface vapor pressures with those of the overlying air it was found that only in the central, cold zone, and there only at midnight could evaporation have ceased. Condensation on the snow surface at other seasons, however, seems to prevail, according, at least, to Wegener's conclusions on the central crossing in the spring of 1913. The summer evaporation from the inland ice must limit appreciably the amount of ice the snowfall can make. Computing the evaporation at 0.3 mm. per day, de Quervain concludes that the annual evaporation if the loss in winter is negligible should be about 55 mm. As this is equivalent to about 15,000 cubic meters of ice, it appears that were it not for evaporation the ice front would stand 7 or 8 km. farther west.

Cloudiness was not great. On the average the sky was less than half cloudy (46 per cent), and clear days were twice as numerous as cloudy (one-third versus one-sixth). The sky was much less cloudy than at the edge of the ice, and markedly clearer than on Nansen's more southern, autumn crossing, when the sky was more than six tenths covered on half the days. While practically all the internationally recognized cloud forms were observed, the large cumuli over the bare coastal strip, and occasional cumuli over the inland ice were the most striking. The The formation of cumulus clouds over the ice sheet had not been expected. It showed that the midday warming there induced a circulation reaching a height of a few hundred meters above the ice. On July 5, cumulus clouds at 500 meters were practically stationary, indicating a restricted vertical extent of the surface wind. Cirrus and cirro-stratus, and alto-cumulus clouds were the most common, each being noted at more than one-third of the observations. Much of what was noted as cirro-stratus after June 19 was the volcanic dust cloud from Katmai. Halos were observed but four times. The dust veil led the eastern Eskimos to fear that next year there would be no summer. With but one excep-

tion the upper clouds moved from some easterly direction, as would be expected, owing to the deep low pressure centers of action to the southwest and southeast. The intermediate clouds, however, averaged from a little west of south, or slightly upslope, representing, probably, the inpouring of air at a moderate height compensating for the outward flow over the ice surface. But little diversion of this wind to the right would be necessary to make it to blow directly upslope and thus yield precipitation.

PRECIPITATION ON THE ICE SHEET.

Though rain is a common phenomenon on the bare land west of the ice sheet, it was observed only once while the party was crossing the inland. Snowfall occurred six times, and in the 5 weeks totaled not more than 17 cm., with a water content of 2 to 2.5 cm. On stormy days, it was difficult to tell whether or not the snow in the air was all wind driven from the surface. On days when snow surely fell, the wind had shifted to upslope directions.

Only in the interior zones, from about 1,800 to 2,400 m. altitude on the west slope and from about 1,200 to 2,300 m. on the east slope, where the snow melted a little in summer, was it possible to determine the approximate amount of annual precipitation. The water content of the annual accumulation here appeared to be about 35 cm., which with 5.5 cm. evaporation makes the probable annual precipitation about 40 cm. In the far interior zone, the precipitation is less, perhaps 30–35 cm. if the trends indicated by the successive determinations on each side may be used as a guide. The average annual precipitation at Jakobshavn is 25 cm., and at Angmagsalik, 100cm.[3] The height of the snow line on the west slope, about 1,450 to 1,500 m., is greater than that on either coast, 1,100 m. at Disco and not more than 1,000 to 1,100 m. at Angmagsalik. The decreasing precipitation toward the interior, the greater brightness of the sun on föhn days, and the general anticyclonic weather, are the important factors in the high snow line of inner Greenland. There is little, if any, effect from rising summer temperature toward the interior, as in the Alps.

An interesting application of barometry was made in determining altitudes while the party was crossing the inland ice. As the ice is devoid of landmarks for triangulation barometric determinations of altitude alone are available. A hypsometer was the standard used, and three "compensated" aneroids were set by it daily. For comparison, barographs were in operation at both ends of the crossing route, and simultaneous observations of pressure and temperature were made at stated hours. On account of the considerable horizontal distances involved it was necessary to consider the weather and wind direction and velocity to make allowance for the horizontal gradient in pressure, before the vertical difference and altitude could be obtained. On the march the aneroids, including a pocket barograph, were used. It was found that a slope of as much as 5 per cent up may be mistaken for a slight down grade. At each camp a theodolite was used to get the depression (zenith distance) of the horizon in 8 directions.

II. SUMMER WEATHER ALONG THE WEST COAST AND ICE FRONT.

The weather of the bare coastal zone on the west is closely related to that of the inland ice, and its effectiveness in melting the ice front is coordinate in importance with the accumulation of snow in the interior. The general meteorological situation over the bare zone is about the reverse of that over the ice cap in summer. The bare zone is much heated by the sun and, thus, is a warm belt between the cold of the inland ice on the one side and the cold of the iceberg-dotted water (Davis Strait) on the other. On account of the expansion and lateral overflow of the heated air, pressure gradients are established toward the warm zone, resulting in a daily sea breeze on the western portion and a daytime intensification of the fall wind off the ice with rising air between. This circulation gives the coasts chilly weather, and causes some daytime cloudiness over the bare zone. (See fig. 1.) The heat of the bare zone is more than sufficient to offset the expansional cooling of sea air as it moves up the slope. Also, the heat hinders the cooling during the hours of low sun to such an extent that the fall wind from the ice can at no time of day continue down to the coast.

Some numerical details from the observations made by the Swiss expedition may be of interest. During the first half of May the temperatures at a fiord head 65 km. from the coast were almost constantly 2° to 4° and once apparently 10° (F.) higher than those at Holstensborg on the coast (lat. 65). Only after very clear nights was the fiord head somewhat colder than the coast, but

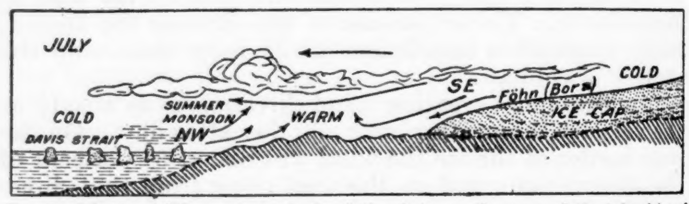

Fig. 1.—Diagram of the summer air circulation between the sea and the inland ice of West Greenland about latitude 68–70°, based on various observations by the Swiss expedition. (After de Quervain, op. cit., p. 212.)

then not as much as 1° (F.). On the inland (glacial) edge of the bare area, about 65 km. back of Jakobshavn, the air temperature at midday in summer was as high as that on the coast, nothwithstanding an altitude 500 m. greater and the practically continuous flow of air off the ice sheet only 600 m. away. In the early morning the temperature there was only 5° (F.) lower than that at Jakobshavn. In the center of the bare zone here the temperatures must have been higher than those so near the ice front and, therefore, higher than on the coast. The effectiveness of the bare zone as a heater may explain in part the average difference of 8° (F.) between a station on the ice and that on the bare land 1 km. away and 50 m. lower. It is a mystery how a wind 12 to 14 miles an hour could be so much warmed in crossing a strip of rocks only 500 to 1,000 m. wide. When a föhn was blowing, the wind went all the way to the coast, where the temperature rose to 15° (F.) above that on the edge of the ice. Normally the difference was 11°.

While there were frequent calms at Jakobshavn, only once was the air still at the ice edge. Southeast winds showed a marked preponderance at both places, though at Jakobshavn, so close to the cold water, the west winds in July were more frequent than the southeast ones. Although there were no fogs on the coast, the sky was more cloudy than at the ice edge, where the descending air was generally unfavorable for cloudiness. The averages in July were 7.1, 6.7, and 6.9 tenths, morning, afternoon, and night, at Jakobshavn, and 5, 5.8, and 6.5 at the ice edge.

The intensity of solar radiation at Holstensborg, altitude 40 m., latitude 66° 56′, was about the same as

[3] A detailed discussion of the relation of this precipitation to the maintenance of the ice sheet, is published in the *Geogr. Rev.*, July, 1923.

that of Montpelier, altitude 44 m., in southern France. On clear days between May 15 and 26 at Holstensborg the average was 1.18, and extremes 1.11 and 1.24 gm. cal. per minute per square centimeter normal to the sun's rays. In the brightest month, April, the average for clear days was 1.16. An observation made August 18 at 2 p.m., in latitude 69° 45′ and 5 m. altitude, gave 0.73. Reduced to the same solar altitude as the May observations, the value would be 0.80, or more than 30 per cent under the intensity in May. This great reduction was owing to the volcanic dust veil. The sun set July 15, for the first time after midsummer, a full week too early. The volcanic dust veil looked like banks of cirro-stratus clouds, flocculent, often undulated, and at times in NW.-SE. bands. Few halos were seen after the advent of the dust. Abnormal atmospheric refractions were observed. The setting sun was much distorted. Mirages were seen strongly developed over the water, where the surface layer of air was notably colder than that above. The green ray, occasionally observed at sunset, was evidently a phenomenon of mirage.

III. WINTER WEATHER AT GODHAVN.

An important phase of the expedition's work was the maintenance of an aerological station at Godhavn, on the south shore of Disco, from October, 1912, to June, 1913. Godhavn and Jakobshavn are under the same general meteorological conditions; near the open ocean on the west, and within reach of the SE. föhn off the inland ice. On account of the marine influence the early winter is wettest and stormiest, while March is the coldest, most quiet, and foggiest month. Godhavn being nearer the open ocean than Jakobshavn it is not surprising that the climate of Godhavn is more marine than that of Jakobshavn. From October to April the monthly temperatures were 2 to 5° F. higher and the cloudiness 1 to 2.5 tenths greater at Godhavn than at Jakobshavn, and the precipitation about twice as great at the former as at the latter. In May and June Godhavn, naturally, had a more prevalent sea breeze blowing daily toward the heated bare zone, and, therefore, was about 2° (F). colder than Jakobshavn in these months. In June there was an east wind of mornings as regularly as a west wind of evenings.

The position of Godhavn on the coast, at the foot of the steep, south wall of Disco 1,000 meters high, and not far from the 1,400–1,500 meter heights of the interior has a considerable effect on the winds. The general easterly and southeasterly wind is deflected into a northeasterly one and reduced in velocity to such an extent that the average at Godhavn is 25 to 30 per cent less than at Jakobshavn. Warm, dry fall winds from the interior of Disco occurred 10 times from October to February, when the open ocean was warmest in contrast to the snow-bound interior. These winds did not extend far out to sea. They caused some local precipitation over the water. Very sudden changes in temperature, upward with the arrival of a fall wind, and downward at its cessation were common. Their relative humidity averaged 20 to 30 per cent. The wind was extremely gusty and turbulent, so much so that kite flying was impracticable. Pilot balloons, showed, however, a south wind usually prevailing above the fall wind from the north. The precipitation at Godhavn in the winter of 1912–13, which was a mild, stormy one, was 201 mm. from October to June, inclusive, of which 80 mm. came in November, and 50 in December. The temperatures did not go extremely low, −13° F. at Godhavn and −17° F. at Jakobshavn, being the lowest for the winter. In all months but March, föhns from the inland ice raised the temperature to above freezing, sometimes even melting the sea ice and driving it away. These föhns made the monthly range more than 45° (F.) in November, January, and February, while in March, when there was no föhn, the range was only 28° (F.) In June the range was greater, 34°, from 30° to 66° F. Fifty-four auroras were observed, mostly as moving draperies in the south.

GENERAL CIRCULATION OF THE ATMOSPHERE ABOUT GREENLAND IN WINTER.

The aerological observations by the expedition in connection with those made at the same time in north-east Greenland, Iceland, and Spitzbergen much needed information concerning the general circulation of the atmosphere in the north polar regions. The pilot balloon work was carried on in May, 1912, and throughout the following winter. Preliminary work had been done in 1909, when 60 ascents had proved so interesting that a complete winter series was planned. Balloons with a computed ascensional rate of 200 meters per minutes, and the de Quervain theodolite were employed. The ascensional rate was found too small for strong turbulent winds, but it is not thought that the results were badly vitiated by this. Observing through the theodolite is not necessarily easy in view of the cold and the wind. Spectacles were sometimes blown off the observer. One third of the balloons were followed to a distance of 24 to 29 km. Smaller distances has to suffice when there was a general, light cirrus sheet. Some of the observation series were very long and trying. The mean height reached was 6 km., while for the ascents where the balloon did not go into clouds the average height was 8 km. The greatest duration of an ascent was 3 hours and 15 minutes, that in which the balloon was thought to have reached a height of 39 km. The greatest distances of disappearance were 132 (?), 42, and 37 km. The results were tabulated by height intervals of 100 to 500 meters. To provide meterologists with an opportunity to study the results in detail a brief account of the weather map and results of each flight is given for the 22 ascents from Holstensborg, April 30–May 29, 13 ascents from Quervainshavn and Jakobshavn, August 3 to September 5, and 82 ascents from Godhavn, September 21, 1912, to May 31, 1913. A special treatment is accorded the longest flight, and some reasons advanced for believing a height of 39 km. was reached.[4]

The significance of the results for the general circulation of the atmosphere is full of some surprises. In the first place, assuming reasonable vertical temperature gradients which would bring the temperature down to −55° C. at 9 km. a northward pressure gradient should obtain over Greenland from as few as 4 km. upward. But there was none such. The upper winds over west Greenland were generally S., indicating gradients toward the west. This could only mean that the cold air overlying Greenland is in but a thin layer, above which the temperatures are surely no lower than those of neighboring low-pressure areas. It is evident that the anticyclone over Greenland is of great vertical extent and that it is probably maintained dynamically. Certain it is that there is no northern circumpolar whirl in these latitudes, according to current theory of the general circulation of the atmosphere, though in the practically

[4] American aerologists are skeptical, however, and believe the balloon must have sprung a leak, thereby reducing its ascensional rate, or even allowing it to descend.

unobstructed Southern hemisphere there may be such a true, circumpolar whirl.[5] The low pressures of Davis Strait and Baffins Bay appear to extend all over the American Arctic Archipelago. The problem of the north polar circulation is still left open, though there is a fair hope of its solution during Amundsen's expedition, in conjunction with which aerological observations are being conducted in the polar regions. There should be a permanent meteorological station in northeast Greenland, which is apparently the north polar, high-pressure center of action.

Occasional captive balloon and kite flights were made at Holstensborg and Godhavn. The weather of May 22–24 was fairly typical of spring conditions at Holstensborg; clear weather began with slowly falling barometer and continued so long as the barometer fell. The wind, at least in the free air, was SE. to S. With rising pressure come W. and NW. winds, with the sky covered with low clouds, stratus and nimbus, and with precipitation. This northwest streaming seems usually to be very thin. There appears to be a direct connection between the inflowing cold, heavy air from the northwest (Davis Strait) and rising barometer. With a layer 1,000 m. thick the rise was 4 mm. but with lesser thicknesses 2 or 3 mm. The wind aloft was föhnlike, from the SE.

The captive balloon was used in midwinter and later, when it was certain there would be enough hydrogen for the pilot balloons. On February 24, a warm winter day, there was an inversion of 4° C., with the maximum temperature at 250 to 400 m. At the time of minimum temperature that day the inversion must have been 8° or 9° C. On the coldest day, March 10, with the minimum −24.7° C., there was no inversion at noon, and practically no wind.

On the 28th to 29th of May eight ascents were made to get the diurnal sequence of temperature. The greatest inversion occurred at 23 h., and thereafter the ground temperature rose, while that aloft sank; the altitude of the maximum temperature usually varied from 150 to 260 m., but at 4 a. m. it was at 400 m. With a sea fog at 6 a. m. the fall in temperature began first at 100 to 300 m. and later at the ground. This made a strong, vertical temperature gradient.

The general results of 83 pilot balloon ascents in Iceland by Thorkelsson were not so great as those in Greenland, for the weather was generally adverse and only when low clouds would not interfere was it practicable to attempt flights. Lack of balloon materials prevented the making of any flights in January before the 29th. South was the most frequent direction of the wind, then W., and NW. NE. and E. winds were absent, partly because flights could not be attempted when such winds occurred, the clouds being too low. It was found that the wind in the lowest 100 m. was governed by the direction of the deep fiord in which the station lay. Winds aloft often did not show any connection immediately with the surface pressure distribution. This may be accounted for by the fact that under some conditions the temperatures make the pressure distribution at even moderate heights differ markedly from those at the surface.

The most pronounced facts from these 83 flights are: On the E. or NE. side of a depression the turn of the wind outwards 50 to 70° was striking. It began to occur at only 2 to 3 km. In a saddle the wind aloft was prevailing west. On the back side of an eastern depression the NW. wind goes to great heights. With the distant approach of a low on the SW., however, the wind may go suddenly to S., or a SE. wind may come in at a different level. The center of a depression leans N. or NW. In many cases, particularly in winter, when there is high pressure to the north the wind aloft is SW. to W., indicating that the cold air which makes the high pressure under such conditions can not be in a very thick layer. Only in October (once) and several times in March and April did the characteristic easterly winds aloft occur with high pressure to the north. This is explained as a result of the anticyclones of winter in this region being a relatively thin layer of cold air, while by spring the overflow from warmer latitudes has so built up the air column that the anticyclone is dynamic. Even in west Greenland there are indications of a more pronounced development of the E. and SE. winds aloft in spring than in winter (partly in fall).

The results of the Spitzbergen flights by K. Wegener and H. Robitsch show characteristic S. to SE. winds with depressions in the SW. and NW. winds with depressions in the SE. No depressions seem to have passed on the north. There are, however, a number of instances, more numerous than the case with E. to NE. winds to heights of 6 km. or more, in which westerly winds prevail aloft (in fall and spring). Especially interesting are the westerly winds above high pressure areas lying north of lows. It seems as if there were here the edge of a true circumpolar whirl, north of the high pressure belt between 70° and 80°N. which bounds the subpolar low-pressure belt.[6] Yet this high pressure "belt" may be merely a wind divide between the Atlantic low and one on the other side of the pole. Whether or not it is such must be determined from more extended observations, such as those Amundsen is making.[7]

[5] Cf. W. H. Hobbs, loc. cit.

[6] V. Bjerknes seems to have used these observations as the basis for a new detail in his general circulation of the atmosphere. See Fig. 31 in *Geofysiske Publ.* No. 5, Kristiania, 1922.

[7] A general review of the work of the Swiss Greenland expedition is published in the *Geogr. Rev.*, July, 1923.

SNOWSTORM OF MAY 8-9, 1923, IN MICHIGAN.

By B. B. Whittier, Meteorologist.

[Weather Bureau Office, Lansing, Mich., June 20, 1923.]

The months of March and April and the first half of May, 1923, were marked by unusually capricious weather in Michigan, with frequent cold waves, which in many localities broke all previous records for low temperature in the months in question. Killing frosts on the 10th and 13th of May were unusually late in the season, but as the cold spring had held vegetation back, and fruit buds were snow covered, the frost caused but little loss. The most unusual feature of the late spring was the snowstorm of May 8–9, which was the heaviest on record for the month of May in the State by a full inch, averaging 3.3 inches for the State, against 2.3 inches for May, 1917, the previous record. What threatened to be a very damaging frost to fruit, much of which was in full bloom, on the morning of the 10th, was minimized by the melting snow on the branches.

The weather map on the morning of May 8 showed a low-pressure area over the Great Lakes, with the main center over northern Lake Huron, and a secondary center over northern Lake Michigan, with high pressure and

colder weather to the north and west. This secondary center of the LOW gave considerable precipitation in the form of snow over the western upper peninsula of Michigan on this date, amounting to about 11 inches in portions of Ontonagon and Gogebic Counties (fig. 1), a very unusual fall for so late in the season even in that section of the State. Comparison may be made with the monthly

FIG. 1.—Snowstorm of May 8–10, 1923, in Michigan.

snowfall for May, 1917, the previous heaviest record for the upper peninsula, when 14 inches was reported in Alger County, and 17 inches on Mackinac Island.

On the morning of the 9th the low-pressure area showed a united center over Lake Erie, the low temperature having overspread the State with west and northwest winds on the surface, forcing the warm, moist air aloft, and heavy snow falling in the southern counties. All previous snowfall records for May were broken on the night of the 8th and on the 9th in the "palm" and "thumb" districts, with 14 inches in eastern Montcalm County, and from 8 to 12 inches from Kent County eastward (fig. 1). Comparison may be made with the total snowfall for May, 1907, the greatest previous snowfall in southern counties, and the second greatest previous record for the entire State. In that month the heaviest fall in the southern portion of the State was 8 inches in southern Lapeer County, a fall of 10 inches near the northern end of the lower peninsula helping to raise the average for the State.

The regular Weather Bureau offices at Grand Haven, Grand Rapids, Lansing, Saginaw, Port Huron, and Detroit, being in the line of heavy snow, all reported falls exceeding previous records by from 2 to 7 inches. (See Table 1 for depths.) The snow was moist and heavy, though soft, and in some sections some damage was caused by breaking limbs, wires, etc., though fortunately the economic damage was surprisingly small. Melting occurred rapidly, especially as the ground was still warm, causing the snow to melt at the bottom and settle. Traffic was considerably demoralized, especially in the eastern counties, where the snow was still falling on the morning of the 9th, but being soft many automobiles ventured forth and soon plowed lanes on the main-traveled highways. By the morning of the 10th most of the snow had disappeared, and by the evening of the 10th this record storm was but a memory.

TABLE 1.—*Stations in the lower peninsula of Michigan reporting 5 inches or more of snow on May 8 and 9.*

	Inches.		Inches.
Edmore	14.0	Port Huron	6.5
Alma	12.0	Battle Creek	6.0
Flint	12.0	Durand	6.0
Millington	12.0	Harbor Beach	6.0
Lansing	11.5	Lapeer	6.0
Saranac	11.0	Lowell	6.0
Croswell	10.0	Plymouth	6.0
Pontiac	9.0	Grand Rapids	5.5
Saginaw	9.0	Grand Ledge	5.0
Sandusky	9.0	Hillsdale	5.0
Bay City	8.0	Howell	5.0
Greenville	8.0	Muskegon	5.0
Owosso	8.0	Port Austin	5.0
Webber Dam	8.0	Grand Haven	4.8
Detroit	6.7		

SNOWSTORM OF MAY 9, 1923, IN THE SAGINAW VALLEY, MICH.

By F. H. COLEMAN, Meteorologist.

[Weather Bureau Office, Saginaw, Mich., May 28, 1923.]

On May 8–9, 1923, there was a very unusual snowfall in the Saginaw Valley, and in fact all of southern Michigan, unusual in view of the fact that snow of any amount rarely falls so late in the season. The ground within the valley limits was covered to a depth ranging from 4 to 14 inches.

At Saginaw, where the depth was 9 inches, records have been kept since 1897, and the greatest previous snowfall in any May was 0.8 of an inch on the 4th in 1907 and the same amount on the 2d in 1909. In no other May was more than a trace recorded.

This investigation covers only the watershed of the Saginaw River, and was undertaken not only because of the unusual nature of the phenomena, but also because of the great destruction wrought by its peculiar character in certain localities.

The snow depth was least over the western portion of the watershed, attained an average depth of 8 to 10 inches in the middle portion, and increased to 12 inches or more over the eastern portion.

As it fell, the snow was very wet, and in the eastern portion of the watershed over an oval-shaped area about 70 miles long and 15 miles wide at the greatest width, it adhered firmly to such objects as branches of trees and telephone and telegraph wires.

In Saginaw, which lay well within this area, it was no unusual sight to see telephone poles bearing the burden of many wires each of which presented the appearance of a cable of snow 2 inches or more in diameter. The weight of these masses of wet, heavy snow not only snapped many wires, but dragged down the cross pieces to which they were attached and even pulled over or broke down many poles. Out of approximately 11,000 telephones in the Saginaw district, nearly 4,000 were put out of commission in this manner.

Many branches of trees of the less sturdy varieties were broken. The damage to cherry and plum trees was especially noticeable, as the opening foliage presented a large surface on which great masses of snow lodged.

Strong convection was evidenced during midday of the 8th by towering cumulus clouds, which were followed by a sharp fall in temperature in the early afternoon accompanied by rain. From 1 p. m. to 4 p. m. the temperature fell from 59 to 39, after which it fell slowly throughout the night and until noon of the 9th, the lowest being 28. The rain turned to snow in the night and ranged from 3 to 7 inches deep by morning and reaching its maximum depth about noon.

The influence of topography is clearly seen. The prevailing winds were west and northwest; where these winds were blowing down the slope of the western portion of the watershed, the snowfall was least, while the greatest snowfall occurred where the air was driven up the slope of the eastern side of the valley.

TORNADO IN DAVIDSON COUNTY, TENNESSEE, MAY 12, 1923.

By R. M. WILLIAMSON, Meteorologist.

[Weather Bureau Office, Nashville, Tenn., May 31, 1923.]

The elongated barometric depression extending from Arkansas to New England on the morning of May 12, 1923, contained some features which usually attend the formation of tornadoes, but it could hardly be considered an ideal type of tornado LOW. The sharp temperature contrast was lacking, at least on the surface. There was a well-defined wind-shift line running northeastward through the trough and a drop in temperature accompanied the shift of wind from the southwest to the northwest, but the change to cooler was only moderate. It was by no means a hot, sultry afternoon in the vicinity of Nashville, the maximum temperature being only 71°, and the temperature change with the shift of the wind not exceeding 10°. The long, narrow trough of low pressure had two centers, one of which was over Indiana at 7 a. m., or due north of Nashville, the other over western Pennsylvania. By 2 p. m., at which time a tornado of considerable violence developed some miles north of this station, the Indiana center had doubtless moved to a location about northeast of Nashville. The tornado, therefore, was distinctly within the southwest quadrant of the storm, another feature which occurs only occasionally. The tornado moved in a general west-east line, although in a part of its course it bore somewhat toward the southeast. That it did not take the usual southwest-northeast direction was due unquestionably to the fact that the pressure trough, by reason of its position and extent, was drawing the winds almost uniformly from the southwest and the shift in direction was from the southwest to west or northwest instead of the usual change from southeast or south to southwest or west.

So far as is known here, only one tornado occurred. It started, apparently, in the north-central part of Davidson County about 8 miles north of Nashville, being first observed near and to the east of some hills that rise 200 to 300 feet higher than the surrounding country. It moved eastwardly across the Dickerson and Gallatin pikes, through the village of Edenwold, across the Cumberland River into the powder plant, and on into the southern part of Sumner County, where it spent its force. The length of the path was about 10 miles. Its width varied from 50 to 200 yards, being determined to some extent, no doubt, by the rolling character of the country. Fortunately, it passed mostly through open country and not much timber was destroyed. A few large trees were in the path, some being uprooted, others twisted into shreds, while still others were carried away entirely leaving only a portion of the trunk standing.

The storm crossed the Dickerson Pike near Lowe's store, about 3 miles south of Goodlettsville. Here one residence and five barns were damaged to the extent of about $2,500. A house a mile or so east of this pike was partly wrecked and a portion of the roof dropped into a yard near Edenwold, more than a mile away. From that point the destruction was of little consequence until it struck a large, handsome residence a little east of the Gallatin Pike, tearing a gaping hole in the roof and wrenching off and carrying away a 2-story veranda extending a distance of 125 feet along two sides of the house. The village of Edenwold, next in its path, suffered severely, several residences, two stores, and the schoolhouse being completely demolished and other buildings partly so. Six persons were injured at this point, one seriously, but, strange to say, no lives were lost. In one instance, there was nothing left of an 8-room cottage except the floor, and yet the occupants, a mother and two daughters, received only slight injuries. A man was buried beneath a pile of brick and débris as the roof of another house collapsed, but escaped with only cuts about the head. One house showed clearly the effect of the sudden expansion of the air within. The roof was entirely gone and two of the walls were flat on the ground, as if pushed outward, while the remaining walls were unharmed. The loss from the storm in the vicinity of Edenwold was probably not less than $35,000, at least half of which was suffered by the large mansion, mentioned above.

The storm turned slightly southeastward from Edenwold, and after crossing a mile or two of open country it devastated an area of the United States Government powder plant (Old Hickory), wrecking seven iron buildings, either partially or totally, the estimated loss being $25,000. Fortunately, the Government stores, consisting of smokeless powder, were not damaged by water as they are contained in water proof boxes. Had the storm taken a different course through the reservation the loss might have been tremendous, inasmuch as the buildings are compactly arranged and represent a total outlay of more than $50,000,000. After leaving the powder plant the storm crossed the river again and continued somewhat southeastward into Sumner County, where it is reported that many trees were uprooted.

TORNADO AT LITTLE ROCK, ARKANSAS, MAY 14, 1923.

By H. S. COLE, Meteorologist.

[Weather Bureau Office, Little Rock, Ark., May 20, 1923.]

A tornado occurred in Pulaski Heights, the western section of Little Rock, between 7:30 p.m. and 8 p.m., May 14. The first trees were uprooted just west of the convent, indicating that the storm originated in that vicinity. It moved northeastward and increased rapidly in intensity as it moved forward. The path of the tornado was about 900 feet wide for the first quarter of a mile, after which it increased in width to about 2,800 feet for the next half mile, then narrowed down to about 1,400 feet and continued about that width to the northern limits of the Country Club grounds where it dissipated. The entire distance traveled was nearly 2 miles.

There were two paths in which all trees were down, indicating that there were two centers moving nearly parallel in the widest portion of the path, the two coming together just beyond the Country Club station or following closely, one after the other. Persons located between the two paths report a severe wind, then a lull for a minute or two and a second storm. The storm moved very slowly, some estimating that it took 15 minutes to pass, but there were no lights and the time was probably overestimated.

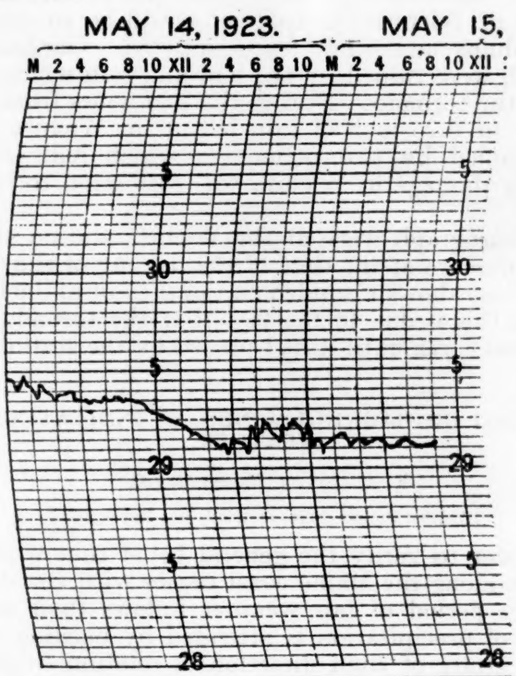

FIG. 1.—Barometric pressure at Little Rock, Ark., May 14, 1923.

The number of trees blown down was unusually large, as there was some heavy pine timber in the path of the storm. Nearly all of the trees were blown to the northeast, and most of them were uprooted instead of broken off. In the two paths of greatest destruction nearly all trees were down; elsewhere a portion of them standing. Three buildings were practically destroyed, one of them a school house, a few were badly damaged, and many slightly damaged. The property damage, aside from the trees that were blown down, was estimated by the Arkansas Democrat at $40,000. Telephone service was cut off, lighting lines were out of commission, and it was 24 hours before car service could be restored. Several instances of houses being nearly destroyed but leaving the persons within uninjured were reported. It is evident that there were no such extremely high wind velocities as are usually reported in such storms, the winds being only high enough to do the damage mentioned.

The tornado occurred about 300 miles east of the center of a crescent-shaped LOW, extending from Springfield, Mo., to Fort Worth, Tex., the lowest readings reported to this office being 29.38 inches. An unusually heavy thunderstorm was in progress in Little Rock and vicinity at the time, lasting from 7 p. m. until a little after midnight. Rainfall continued at an excessive rate for two hours and five minutes, 3.21 inches occurring from 7:26 p. m. to 9:31 p. m. Heavy rainfall occurred in all portions of the State during the afternoon and night, the heaviest reported being 9 inches at Hot Springs National Park. Although the electric lights were cut off at the home of the writer little inconvenience was experienced in going about the house as the flashes of lightning were almost continuous. It was not possible to see that a tornado was occurring less than 3 miles distant, but it was plainly evident that the most intense portion of the storm was in the locality in which the tornado occurred.

SMALL TORNADO AT THRALL, TEXAS, MAY 14, 1923.

By W. D. FULLER, Meteorologist.

[Weather Bureau Office, Taylor, Tex., May 16, 1923.]

On Monday night, May 14, 1923, a small tornado occurred at Thrall, Tex., a town about 7 miles east of Taylor. On account of the darkness no pendent cloud was observed, but the effects of the disturbance showed plainly that it was tornadic in character.

The storm traveled from southwest to northeast over the short course that could be traced, but owing to the fact that the immediate section where it occurred is sparsely settled, and that crops are not far enough advanced to show the track very distinctly, extensive observations were not possible.

A house about 14 by 30 was picked up, lifted over a fence without touching the latter, and deposited about 50 feet to the northeast. In its original position the house faced south, but when deposited it faced north. It was wrecked when it fell to the ground. A barn of larger dimension was wrecked after being moved about 10 feet. The débris in each case showed clearly a rotary motion of the storm counterclockwise. A few trees were twisted off at the roots. As far as can be learned, the tornado touched only at this point in its course.

Thunderstorm conditions prevailed at Taylor during this disturbance, but nothing unusual was observed here. The barograph trace showed about a tenth of an inch rise during the three hours from 5 p. m. to 8 p. m., was steady for about two hours, then showed a quick rise of nearly a tenth of an inch in about 20 minutes at the time of the tornado 7 miles away, which was between 9:30 p. m. and 10 p. m. The monetary damage was not large, probably not exceeding $600.

TORRENTIAL RAINS IN EXTREME SOUTHEASTERN TEXAS.

ERNEST CARSON, Observer.

[Weather Bureau Office, Port Arthur, Tex., June 15, 1923.]

On Friday, May 18, 1923, during a severe thunderstorm, torrential rains fell over the extreme southeastern portion of Texas, Beaumont and Port Arthur reporting the greatest amounts, 13.54 inches and 5.38 inches, respectively.

The rain at Beaumont began shortly after midnight of the 17th and ended about noon of the 18th. A stick measurement at 7 a. m. showed 0.78 inch; the rain continued falling lightly until 7:30 a. m., being shortly before this time when the first thunder was heard; then the torrential rain began and continued until 10 a. m. It was stated that practically the entire amount of rain fell during the two and one-half hour period from 7:30 a. m. to 10 a. m.

Streets were flooded to a depth of 1 to 5 feet, the water backing into business houses and causing considerable damage to the contents. No automatic gauge record was obtainable at Beaumont, but an idea of the volume of water that fell can be had from a description of the topography. It is situated on a level country on the west bank of the Neches River, with a natural slope toward the river. Although with the natural drainage and the sewerage system the city was flooded, as stated above and shown by Figure 1, which was taken on Pearl Street about 300 yards from the river.

Street car and interurban traffic were completely demoralized for five hours, and where streets were paved with wooden blocks swelling took place, and the blocks buckled and floated away. During the storm lightning struck several buildings in the city and an oil-storage tank at a near-by refinery, burning all the oil in the tank. Total damage was estimated at $500,000, practically all from water.

One death was reported. A negro riding horseback was drowned when the horse fell with him in a large drainage ditch near El Vista, Tex., which is a few miles south of Beaumont.

At Port Arthur a light rain fell from 4:28 a. m. to 6:57 a. m.; first thunder was heard in the west at 5:50 a. m. Rain began falling again at 7:40 a. m. and ended at 1:14 p. m.; during this time 5.37 inches was recorded. There were two excessive periods, the first from 9:20 a. m. to 10:24 a. m., 3.25 inches falling, and the second from 11:02 a. m. to 11:41 a. m., 1.86 inches falling. It is evident from the changes in wind direction that two thunderstorms passed over the station in rapid succession. Rainfall was heaviest during the first storm; accumulated depths during excessive rate were 1.27 inches in 15 minutes, 2.11 inches in 30 minutes, and 3.11 inches in 1 hour.

No damage occurred in Port Arthur; the water did not obtain any great depths and all disappeared soon after the storm passed, except in the western part of the city, where it was left standing for several hours, due to an accident to one of the drainage pumps.

THE CLONMEL TORNADO OF MAY 22, 1923.

By JAMES W. ARNOLD, Observer.

[Weather Bureau Office, Wichita, Kans., June 4, 1923.]

On the evening of May 22, 1923, a tornado occurred in the vicinity of the Wichita station, injuring 5 people, causing property damage in excess of $100,000, and crop damage which can not be estimated at the present time.

The first evidence of the tornado was near Viola, Kans., approximately 23 miles southwest of the Wichita station. Assuming a north-northeast to northeast direction it struck again at a point about 4 miles southwest of Clonmel, continuing to a point about 4 miles northeast of the latter place. Here it lifted and no further evidence of damage to buildings was found until the vicinity of Twenty-ninth Street and Arkansas and Lawrence Avenues, North Wichita, was reached, where it dipped down to earth again, causing injury to people and property damage.

The total length of its path was about 30 miles and its width 1 mile. The length of the path of greatest destruction in the Clonmel vicinity was 7 to 8 miles, the center of the path passing through the center of the village, while in North Wichita the length was about 1 mile.

A distinct funnel-shaped cloud was seen by residents of Clonmel and the direction of the prostrated trees indicates that the storm was of tornadic character. No one in the vicinity of North Wichita saw a funnel-shaped cloud, but two persons who have seen other tornadoes said they heard the distinct roar which accompanies them.

The rate of travel was slightly less than 60 miles per hour. A clock at Clonmel, damaged by the storm, stopped at 8:55 p. m., while one at Wichita, also broken by the storm, stopped at 9:30 p. m. The distance traversed in 35 minutes being about 30 miles.

In the Clonmel section about 12 farmsteads were damaged and practically every building in the village was damaged. The total property loss was about $50,000 and crop damage can not be estimated, although about 10 per cent of the corn and 60 per cent of the kaffir and feed crops may have to be replanted. The crop damage was not confined to sections where the tornado did property damage, but all along the 30 mile path crops were harmed considerably. In many places in the near vicinity of Wichita the apple crop will be an entire loss, while plums and other fruits suffered. Gardens along the path were ruined by the hail and rain which accompanied the tornado. During the two hours from 9 p. m. to 11 p. m. 0.75 inch of rain fell at the Wichita station, accompanied by two periods in which hail fell. The property damage in Wichita was estimated to be about $50,000.

The barograph trace at the Wichita station shows no fall in pressure at the time of the passing of the tornado, but instead shows a sudden rise of 0.10 of an inch. It is thought this is due to the fact that the tornado did not dip to the earth until it had passed by the station.

VEERING OR BACKING WINDS AS INDICATING THE WEATHER.

E. P. JONES, Meteorologist.

[Weather Bureau Office, Portland, Me., May 3, 1923.]

In order to verify the general belief that when precipitation along the Maine coast ceases with veering winds a longer period of fair weather follows than when the ending of precipitation is attended by backing winds, a careful study of wind direction in relation to precipitation from November 1, 1922, to March 30, 1923, resulted in proof that the validity of this assumption is not sustained by fact, as may be seen from the accompanying table.

Rain or snow was more often followed by backing winds, while the period of fair weather before the next following precipitation was somewhat longer after backing winds.

	Number of times wind—		Average period before next following precipitation.	
	Veered.	Backed.	After veering.	After backing.
November	1	3	114 hours or 4.8 days	96 hours or 4 days.
December	3	9	30 hours or 1.2 days	60 hours or 2.5 days.
January	5	5	30 hours or 1.2 days	28 hours or 2.8 days.
February	3	5	48 hours or 2 days	81 hours or 3.4 days.
March	8	6	52 hours or 2.2 days	42 hours or 1.8 days.
Total	20	28		
Average	4	6	55 hours or 2.5 days	69 hours or 2.9 days.

Fig. 1.—Pearl Street (looking north), Beaumont, Tex., May 18, 1923.

NOTES, ABSTRACTS, AND REVIEWS.

MEETING OF THE AMERICAN METEOROLOGICAL SOCIETY TO BE HELD IN LOS ANGELES, CALIFORNIA, SEPTEMBER 17-19, 1923.

The Pacific Branch of the Association for the Advancement of Science has kindly invited the western members of the American Meteorological Society to meet with them at their annual meeting in Los Angeles, Calif., on September 17, 18, 19, 1923. In response to a questionnaire about 22 members of the A. M. S. have signified their desire to attend and present papers on that occasion. This will insure a successful meeting, as very likely there will be more to come later. Quite a number stated they could not this early say positively that they would be on hand for the meetings; but would advise the secretary pro tem at a later date if they found it possible to be there.

It is proposed to hold a symposium on the relation of the weather to forest fires, which will be of interest to the meteorologists and to Forest officials connected with our National Forests, as well as to those interested in privately owned timber. Also at least half a day will be taken up with matters pertaining to evaporation and to precipitation in the mountains as affecting the run-off of streams from which water is employed for irrigation and hydroelectric purposes.

Other papers will be presented pertaining to nearly every branch of meteorology and these, together with their discussion, will provide food for thought for some time to come. Our members will be invited to the entertainments given by the citizens of Los Angeles to the Pacific Branch of the American Association for the Advancement of Science, and all will share in the reduced transportation rates that will be available at the time of the meeting.—*E. A. Beals, Secretary Pro-tem.*

POLAR-FRONT THEORY OF THE STRUCTURE OF CYCLONES DISCUSSED BY THE ROYAL METEOROLOGICAL SOCIETY.

[Reprinted from *The Meteorological Magazine*, May, 1923, p. 84.]

The monthly meeting of the society was held on Wednesday, April 18, 1923, at 49 Cromwell Road, South Kensington, Dr. C. Chree, F. R. S., president, in the chair.

W. H. Dines, F. R. S., and L. H. G. Dines, M. A.—An examination of British upper-air data in the light of the Norwegian theory of the structure of the cyclone.

The theories of the Norwegian school of meteorologists, which have occupied so much attention during the last few years, were formulated without much reference to upper-air observations, and the desirability of a scrutiny of such observations as are available is manifest. Such a scrutiny has been made by the authors of this paper, and the results are disappointing.

The first method adopted was to select from the occasions on which *ballon sonde* records were available, those on which the synoptic charts indicated that it was likely that the balloon had passed through the polar front. Graphs showing the relation of temperature to height were drawn for these occasions, and compared with graphs for other occasions, selected more or less at random. It was found that there were no striking differences between the two groups, inversions of temperature occurring with about the same frequency.

A second problem, the relation between humidity and temperature, was attacked by utilizing the kite ascents made at Pyrton Hill. It was found that an inversion of temperature was nearly always associated with a decrease in the humidity, whereas the Norwegian theory requires an increase.

The conclusion reached is that the observational evidence fails to support the hypothesis that the superposition of equatorial over polar air is a characteristic feature of the structure of a cyclone. The speakers who took part in the discussion showed great reluctance to to accept this conclusion. Further examination of the material is evidently desirable.

FROST RECESSION FROM GROUND IN ALASKA.

[Reprinted from *The Official Record*, Department of Agriculture, Washington, June 6, 1923.]

Travelers and others in Alaska have frequently commented on the frozen earth that lies just under the blanket of moss so common throughout much of the Territory, and this has led many to believe that crop production could not be made successful in much of that country. The experience at the experiment stations in the interior of Alaska is quite to the contrary. In many parts the ice is not permanent except under the layer of moss. When this is removed the stratum of permanent ice recedes and agriculture becomes possible.

At the Rampart station, which is situated within about 50 miles of the Arctic Circle, grain growing has been carried on successfully for more than 20 years. The first clearing was made in 1900 and a layer of moss removed from the land. At that time the soil was frozen to within 8 inches of the surface. After one summer's exposure the ice had melted to a sufficient depth to permit the first crop to be planted. The ice layer has now receded to a depth of 6 or 7 feet and it is still gradually being lowered.

The presence of this frozen subsoil is not without advantage in the interior of Alaska, where the rainfall is light and dry seasons sometimes prevail. At such times the moisture from below is brought to the roots of plants by capillarity and crop production is assured.

The receding of the permanent ice is shown in other ways. At the Holy Cross Mission, on the lower Yukon River, a well was dug in the summer of 1899 to a depth of 25 feet and no permanent ice encountered. The place where the well was dug had been under cultivation for about 10 years.

At the Fairbanks station in the spring of 1909 a well 40 feet deep was dug and no frost met with except in the first 2 feet on land cleared in 1907.

These instances show that if the moss is removed the ice will thaw to a greater depth in summer than it freezes in winter.

WATER BALANCE IN THE PANAMA CANAL, DRY SEASON OF 1923.

By R. Z. KIRKPATRICK, Chief Hydrographer.

Figure 1 shows concisely the amount of water available for all uses at the Panama Canal during the dry season of 1923 and the amount available as storage at the beginning of the rainy season May 1, 1923.

MORTALITY FROM HEAT AND SUNSTROKE.

[Reprinted from *Statistical Bulletin*, Metropolitan Life Insurance Co., May, 1923, p. 6-8.]

The greatest variations occur from year to year in the number of cases of and deaths from heat prostration and

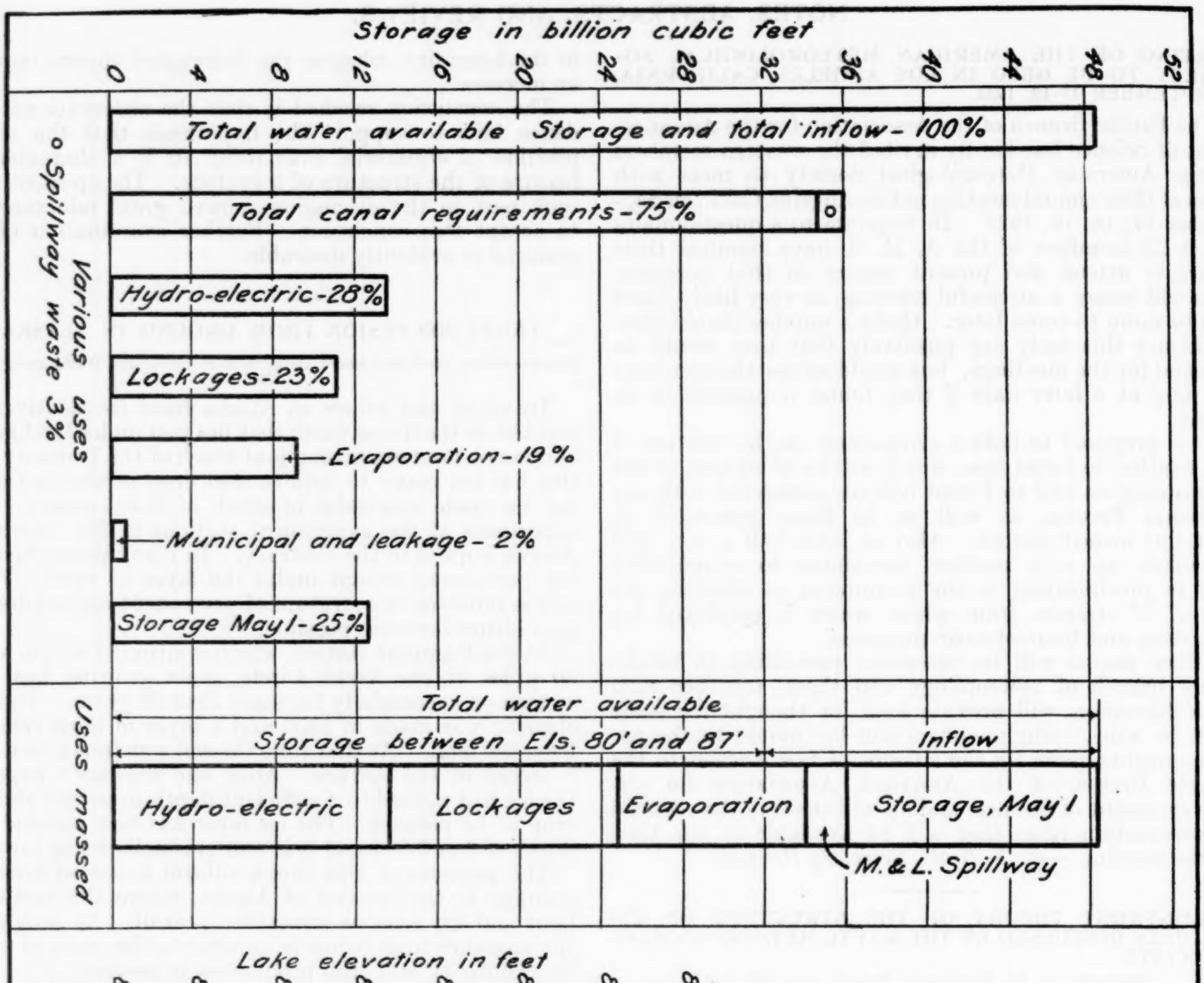

FIG. 1.—The uses and losses of Gatun Lake, dry season, 1923.

sunstroke. Their occurrence is dependent, obviously, upon conditions of atmospheric heat and humidity. When the summer months of any year are featured by frequent and protracted periods of high temperature, there result relatively large numbers of both fatal and nonfatal heat strokes.

How great are the variations in the death rate from this cause in various years will be news to the average person. Few realize that fatal heat prostrations could be 33½ times as numerous in one year as in another. Yet this is precisely what has happened among the industrial policyholders of the Metropolitan Life Insurance Co. during the period 1911 to 1922. In 1911, 6.7 policyholders per 100,000 died from the effects of heat; while in the year 1920, only 0.2 per 100,000 died from this cause. For the United States registration area, rates are available for a period of 21 years (1900 to 1920, inclusive). Here there is even a larger margin between the maximum heat fatality rate, which was 12.8 per 100,000 in 1901, and the minimum, which was 0.3 in 1920. There were about 43 times as many deaths from heat and sunstroke per 100,000 population in the maximum as in the minimum year. For no other single cause has there been as marked variation in the death rate during the past two decades as for heat and sunstroke.

Heat fatalities register a much higher death rate among males than among females. This is inevitable because men are engaged in occupations which subject them more often to the hazards of heat. Colored persons have a higher death rate than whites and this can not be ascribed to the fact that colored people are relatively more numerous in the South. Experience has shown that even in the Southern States, the heat prostration death rate of colored persons exceeds that for whites.

The fact is that the highest death rates from the effects of heat are not found, as might be supposed, in the Southern States. North and South Carolina, for example, show, year after year, very low death rates from this cause, and the figures for Kentucky, Tennessee, and Virginia are well below the average for the registration area. The lowest rates usually prevail in the Mountain States, particularly in Colorado and Montana; in Washington on the Pacific coast, and in Maine and Vermont of the New England States. The States which in most years show above-average rates are Michigan, Wisconsin, Indiana, and Ohio in the East North Central region, particularly the first two; all of the Middle Atlantic States, New York, New Jersey, and Pennsylvania; Connecticut and Rhode Island in New England; Maryland in the South Atlantic region and Missouri in the West North Central section.

Comparison of the figures year after year shows clearly that the death rate from this cause is very much higher in the cities than in the rural districts. This is unquestionably due to the environmental conditions that obtain for city workers and city dwellers as well as their lower resistance. Those engaged in agricultural pursuits are notably less subject to the effects of heat.

Mortality from this cause has a very decided age incidence. Infants are particularly susceptible and elderly people are even more so. About one-half of the deaths from heat and sunstroke are those of persons over 50 years of age. It is obvious that during the heated season nothing should be left undone to protect infants from exposure and to give all possible attention to their diet. Older persons should guard as much as possible, not only against exposure to high temperatures, but against overactivity during the summer months.

THE NATURE OF INSENSIBLE PERSPIRATION IN HEAT REGULATION.

[Editorial from *The Journal of the American Medical Association*, July 1, 1922, p. 45, vol. 79, No. 1.]

Every person continually experiences a loss of water from the skin in quantities that may become not inconsiderable under certain circumstances. The cutaneous excretion of water is determined mainly by the need for regulating the temperature of the body, so that the amount leaving by way of the skin depends on the heat production of the body or on the external temperature, and is very little affected by the quantity of fluid consumed. Under ordinary conditions, in which no visible collection of fluid on the skin surfaces occurs, the water lost is included in the so-called insensible perspiration. According to observations on anomalous persons without sweat glands, the evaporation of water from the nonsweating skin may amount to 800 gm. (28 ounces) a day. In normal persons it will be noticed that the quantity of water thus given off increases with a rise of environmental temperature slowly up to a certain degree, and then rises rapidly. This sudden increase occurs simultaneously with the activity of the sweat glands, resulting in the formation of visible sweat. The insensible perspiration is therefore conventionally regarded as represented by evaporation of water from the surface of the cuticle itself apart altogether from the sweat glands. If the removal of heat through the loss of water by insensible perspiration is purely a physical process, as it is commonly assumed to be, the transfer should be affected not only by temperature factors but also, to some extent at least, by the humidity of the surrounding air. If the skin is to be regarded, so far as the insensible perspiration is concerned, merely as a membrane through which water is diffused into air, obviously the process should be retarded when the external medium tends to be more saturated with moisture. Several investigators have found, however, that in fact this is not necessarily the case. Most recently, for example, in Schwenkenbecher's clinic at Marburg, Moog [1] has observed that at a fairly constant temperature of 25° C. (77 F.) increases of from 30 to 40 per cent in the relative humidity may actually be attended by increased invisible perspiration through the skin. If such data are accurate, one can not escape the conviction that this loss, instead of being merely a purely physical process dependent on the composition and temperature of the air, is a physiologic one varied by the necessities of heat regulation in the body. Perhaps we may think of it, with Schwenkenbecher, as an insensible secretion of sweat rather than a mere diffusion of water through the skin membrane.

THE RYKATCHEF FAMILY.

[Reprinted from *Nature*, London, May 26, 1923, p. 716.]

News has reached this country [England] of the family of the late General Rykatchef, who was director of the Russian Meteorological and Magnetic Service until shortly before the war.

General Rykatchef died on April 1, 1919, his wife on November 22 of the same year. The last survivor of three sons died on February 24, 1920. A son-in-law perished on July 6, 1919, leaving five young children. They, with their mother and her sister, who is well known to meteorologists and magneticians as her father's constant companion on his international journeys, are the only survivors of a once large family.

[1] Moog, O.: Der Einfluss der relativen Luftfeuchtigkeit auf die unmerkliche Hautwasserabgabe, Deutsch. Archiv. f. klin. Med. 138: 181 (Jan. 24) 1922.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1923.

By HERBERT H. KIMBALL, In Charge, Solar Radiation Investigations.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, **48**:225, and a note in the REVIEW for November, 1922, **50**:595.

From Table 1 it is seen that direct solar-radiation intensities averaged slightly above the normal values for May at Madison, Wis., and Lincoln, Nebr., and close to normal at Washington, D. C. A noon intensity of 1.49 gram-calories per minute per square centimeter of normal surface measured at Madison on May 9 exceeds the previous maximum intensity for May measured at that station by about 1 per cent.

Table 2 shows that slightly more than the average solar and sky radiation was received on a horizontal surface at Washington and Madison during the month, and slightly less than the average at Lincoln.

Skylight-polarization measurements obtained at Washington on 14 days give a mean of 53 per cent, with a maximum of 67 per cent on the 9th. At Madison, measurements obtained on 6 days give a mean of 61 per cent, with a maximum of 70 per cent on the 17th. These are slightly above average values for May at the respective stations.

TABLE 1.—*Solar radiation intensities during May, 1923.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass. A. M.					Air mass. P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 1	4.75	0.69	0.82	0.98	1.17	1.38	1.02				5.16
2	5.36		0.63	0.78	1.03	1.17					4.57
3	7.04				1.05	1.25	0.93	0.73	0.58		5.36
4	7.87	0.61	0.69	0.83	1.00	1.25					5.36
7	9.14							0.92			4.95
9	3.45				1.30	1.46					3.81
10	3.30	0.76	0.86	0.99	1.22						3.00
11	6.50			0.84	1.04	1.30					5.16
14	4.75			0.78	0.98	1.20					5.79
17	5.56		0.74	0.90	1.08	1.33					5.36
18	7.57			0.71	0.89						6.76
25	7.04	0.56	0.69	0.84	1.03	1.34					6.02
31	9.47		0.55	0.67	0.88	1.14					9.47
Means		0.66	0.71	0.83	1.06	1.28	(0.98)	(0.82)	(0.58)		
Departures		+0.02	−0.02	+0.01	+0.06	−0.02	−0.02	+0.04	−0.12		

Madison, Wisconsin.

Date.	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
May 4	6.76						0.88				7.29
5	4.17			1.07	1.20						4.95
9	3.45				1.33	1.52					3.99
10	3.63					1.28					6.50
17	5.16				1.28	1.42					3.45
25	5.79				1.13						5.79
31	7.04				1.06						6.76
Means				(1.07)	1.20	1.41	(0.88)				
Departures				+0.11	+0.08	+0.06	−0.15				

TABLE 1.—*Solar radiation intensities during May, 1923*—Continued.

[Gram-calories per minute per square centimeter of normal surface.]

Lincoln, Nebraska.

Date.	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
	75th meridian time.	Air mass.									Local mea solar time.
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 4	6.27	......	......	1.13	1.26	1.51	1.23	1.01	0.88	0.87	4.95
7	9.14	......	......	......	1.14	......	1.24	1.05	0.93	0.82	7.29
8	3.15	......	......	......	......	......	1.31	1.12	0.97	0.85	2.26
9	3.81	0.73	0.95	1.09	1.25	1.43	1.16	0.92	0.78	0.67	2.87
16	4.75	......	......	1.04	1.26	......	......	......	......	......	4.57
25	7.04	......	......	......	1.18	......	......	......	......	......	6.27
26	8.48	......	0.67	0.82	1.11	1.39	1.19	1.02	0.88	0.74	5.56
Means	......	(0.73)	(0.81)	**1.02**	**1.20**	**1.44**	**1.23**	**1.02**	**0.89**	**0.79**	......
Departures	......	**−0.05**	**−0.01**	**+0.05**	**+0.05**	**+0.06**	**+0.12**	**+0.08**	**+0.10**	**+0.05**	......

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
May 7	416	490	666	−63	+22	+174	−2,853	+994	+2,288
14	459	434	495	−29	−44	−14	−3,054	+689	+2,187
21	579	593	464	+86	+113	−44	−2,449	+1,483	+1,878
28	501	516	535	+5	+28	+14	−2,413	+1,677	+1,976

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average barometric readings for the month were from three-hundredths to one-tenth of an inch below the normal at land stations in Newfoundland, Nova Scotia, the Azores, the West Indies, and on the Atlantic coast of the United States. The average pressure at Valentia, Ireland, was somewhat higher than usual, while at London it was nearly normal.

The number of days on which fog was reported over the western part of the ocean was unusually large, and in the 5-degree square between latitude 40°–45° N., longitude 45°–50° W., it occurred on 19 days, a percentage of 61, as compared with the normal of 35 shown on the Pilot Chart; it was nearly as prevalent over the region between the 50th meridian and the American coast, the percentage ranging from 45 to 52. Fog was also frequently encountered over the middle section of the steamer lanes, while the European coast was comparatively free.

There was a most noticeable falling off in the number of days with winds of gale force as compared with April, and over the major part of the ocean the number was below the normal for May. The greatest number was reported from the 5-degree square between latitude 40°–45° N., longitude 45°–50° W., where it occurred on 5 days. It is a strange coincidence that in this same square the maximum amount of fog was recorded. Gales were reported on 4 days in the square immediately to the south and on from 2 to 3 days in the middle section of the steamer lanes, while they were not reported on more than 1 day in any 5-degree square east of the 30th meridian.

From the 1st to the 3d moderate weather was the rule over the entire ocean, with the exception of a slight disturbance in mid-ocean on the 2d and 3d.

On the 4th there was a fairly well-developed LOW central near latitude 40° N., longitude 62° W., its influence extending over a contracted area between the 37th and 47th parallels. Storm log:

American S. S. *Chickasaw City:*

Gale began on the 3d, wind NNE. Lowest barometer 29.60 inches at 1 a. m. on the 4th, wind NW., 8, in latitude 38° 18′ N., longitude 63° 35′ W. End at 2 p. m. on the 4th, wind W. Highest force of wind 9, NW., shifts NNW.-NW.-N.

On the 5th and 6th, while there were no depressions of any consequence over the ocean, reports were received of moderate gales on the latter date in the central and eastern sections.

On the 7th an area of low pressure covered Newfoundland; this moved slowly eastward, the center being near St. Johns on the 8th, with gales over a restricted area in the southeastern quadrant. Storm log:

French S. S. *Syria:*

Gale began on the 8th, wind S. Lowest barometer 29.78 inches from 2.30 to 7 p. m. on the 8th, wind S., 8, in latitude 39° 35′ N., longitude 46° 20′ W. End on the 8th, wind W. Highest force of wind 8, S.; steady S.

From the 9th to 11th favorable conditions prevailed, with the exception of moderate gales over a limited area in mid-ocean, and on the latter date they were also reported off the British coast.

British S. S. *Parthenia:*

Gale began on the 10th, wind NE. Lowest barometer 29.20 inches at 6.30 p. m. on the 10th, wind NE., 7, in latitude 58° 50′ N., longitude 7° 20′ W. End on the 11th, wind N. Highest force of the wind 8; shifts NE.-N.

Charts VIII and IX show the conditions on the 12th and 13th, respectively, when there was a disturbance in the region between the 35th and 45th parallels and the 40th and 60th meridians, and southwesterly gales were also reported off the American coast between Hatteras and New York. Storm logs:

British S. S. *Bolivian:*

Gale began on the 12th, wind NW. Lowest barometer 29.71 inches at 6 a. m. on the 12th, wind NW., in latitude 40° 16′ N., longitude 51° 04′ W. End on the 13th, wind NW. Highest force of wind 9; steady NW.

American S. S. *Currier:*

Gale began on the 12th, wind SW. Lowest barometer 29.75 inches at 2 p. m. on the 12th, wind SW., 7, in latitude 35° 55′ N., longitude 75° 22′ W. End on the 13th, wind SW., 6. Highest force of wind 8, SW.; steady SW.

On the 14th and 15th nothing unusual was reported, except that one vessel encountered heavy weather in southern waters, as shown by following storm log:

Italian S. S. *Ida Z. O.*

Gale began on the 13th, wind NW. Lowest barometer 29.84 inches at 2 a. m. on the 13th, wind NW., 6, in latitude 32° 20′ N., longitude 43° 30′ W. End on the 15th, wind NW. Highest force of wind 8, NW.; steady NW.

On the 16th and 17th easterly winds of gale force prevailed over the eastern and middle sections of the ocean, and on the former date one vessel reported snow near latitude 45 °N., longitude 24° W. On the 17th southerly gales were also reported along the American coast between Hatteras and Nantucket. Storm log:

British S. S. *Exeter City:*

Gale began on the 16th, wind E. Lowest barometer 29.78 inches at midnight on the 16th, wind E., 7, in latitude 44° N., longitude 36° 15′ W. End on the 18th, wind E. Highest force of wind 7, E.; steady E.

From the 18th to the 20th unusually quiet weather prevailed over practically the entire ocean. On the 21st there was a disturbance in the region southwest of the Azores, as shown by the following storm log.

Italian S. S. *Federica:*

Gale began on the 21st, wind SSW. Lowest barometer 29.72 inches at 6.40 a. m. on the 21st, wind WSW., 8, in latitude 34° 55′ N., longitude 34° 50′ W. End at 10 p. m. on the 21st, wind WSW. Highest force of wind 9; steady WSW.

From the 22d to the 24th summer conditions were again the rule, with here and then an isolated vessel that encountered fairly strong winds.

On the 25th the northern European coast was visited by northerly gales that covered a limited area. Storm log:

American S. S. *West Modus:*

Gale began on the 24th, wind NW. Lowest barometer 29.72 inches at 6 p. m. on the 24th, wind NW., 7, in latitude 59° 10′ N., longitude 10° 10′ W. End on the 25th, wind NNE. Highest force of wind 8, NNE.; shifts W.-NW.-N.-NNE.

On the 26th and 27th St. Johns, Newfoundland, was near the center of an area of low pressure, and while moderate weather prevailed in that vicinity a few vessels encountered gales in the territory between the 40th and 50th parallels and the 30th and 50th meridians, as shown by following storm log:

Italian S. S. *Piave:*

Gale began on the 26th, wind W. Lowest barometer 29.71 inches at 4 p. m. on the 26th, wind W., 9, in latitude 42° 30′ N., longitude 43° 54′ W. End on the 26th, wind WNW. Highest force of wind 10; shifts not given.

On the 28th the barometric reading was still comparatively low at St. Johns, although by the 29th it had risen considerably. On the 30th the pressure was high over the entire ocean, with the exception of the Gulf of Mexico, and light to moderate winds were reported from that locality. The following storm log was the only one received for the 30th:

American S. S. *West Modus:*

Gale began on the 30th, wind S. Lowest barometer 30.14 inches at 8 a. m. on the 30th, wind S., 6, in latitude 47° 32′ N., longitude 38° 13′ W. End of gale on the 30th, wind SW. Highest force of wind 8, S.; shifts S.-SW.

On the 31st a deep depression appeared, central near latitude 40° N., longitude 55° W., although judging from reports received, its influence did not extend far. Storm log:

British S. S. *Wells City:*

Gale began on the 30th, wind SE. Lowest barometer 29.14 inches at 4 a. m. on the 31st, wind WSW., 8, in latitude 41° 09′ N., longitude 56° 07′ W. End on the 31st, wind N. Highest force of wind 8, NW.; shifts SE.-SW.-NW.-N.

NORTH PACIFIC OCEAN.

By WILLIS E. HURD.

The incoming of summer conditions was well portrayed by the weather of May over the North Pacific Ocean. There was some rough weather over the northern routes, but the Aleutian LOW which, during the cooler months, exercises so major a control over the meteorological events in this region, could be seen as appreciably weakening. Therefore the gales experienced by steamers traversing these waters were less severe. The winter HIGH which continued along the China coast in April practically lost its identity in May, and the northeast monsoon seems in great measure to have given place to the transition weather normal to the season in lower Asiatic waters. Several storms appeared in this region, but most of them were of continental origin and of only moderate intensity. The one disturbance of considerable moment in the Far East was a typhoon, which will be mentioned later.

East of the 180th meridian the North Pacific HIGH practically controlled the weather over a great area after the 9th. Early in the month the weather of the region midway between the United States west coast and Hawaii was unsettled and the pressure moderately low until the 9th; thereafter the HIGH occupied its normal position with a crest of about 30.20 inches during the second decade. After the 20th the HIGH moved westward and intensified, so that its center, with an average pressure of 30.40 inches, lay near latitude 40° N., on the 155th meridian of west longitude.

In the Mexican coast region the weather was considerably affected by the fairly persistent low-pressure area which fluctuated over Mexico and the southwestern portion of the United States, giving frequent fresh northwesterly winds along the coast from San Francisco to Cape San Lucas and even farther southward, especially during the latter half of the month. South of the 15th parallel calms and light variable winds prevailed. Over the Gulf of Tehauntepec northeasterly to northwesterly winds of gale force were reported upon several occasions. On the 9th and 10th these gales reached a force of 9. On the 9th a gale of force 8 from north-northeast occurred in latitude 10° 50′ N., longitude 88° 49′ W. However, there were no pressure disturbances noted in this region.

At Honolulu pleasant weather was experienced. The prevailing wind was from the east, with maximum velocity, 33 E., occurring on the 24th. The average hourly velocity was 10.6 miles an hour, or 2.3 miles higher than the 19-year average. Sunshine was normal, but the rainfall, 0.36 inch, was 1.38 inches less than the normal, and the month was the third driest since 1905. Dry weather also prevailed on the California coast, San Francisco receiving only 7 per cent of the normal amount for May.

On the 3d and 4th of the month a storm moving eastward from Japan gave rise to moderate gales. On the 3d the American S. S. *President Taft* experienced a southerly gale, force 8, lowest pressure 29.63 inches, in latitude 34° 45′ N., longitude 141° E., and on the following day the Japanese S. S. *Toyooka Maru* reported a gale of force 8 from the south-southeast, lowest pressure 29.65 inches, in 39° 40′ N., 150° 10′ E. No further reports of the storm are available.

On May 5 signs of a tropical disturbance appeared to the southward of the Bonin Islands. On the 6th the disturbance moved northeastward, increasing in energy to a typhoon, and at noon was reported central near latitude 25° N., longitude 140° E. The British oil tanker *Adna*, Hongkong toward San Francisco, came within the influence of the typhoon on the 6th, and remained there until the 8th, but although it experienced rough seas, did not encounter winds of force higher than 7. The vessel, however, received reports of the typhoon's

activities which bespoke for it a considerable intensity. At 6 p. m. of the 6th the storm was reported in latitude 30° N., longitude 144° E., with an observed pressure of 28.74 inches. At noon of the 7th its position was placed in 35° N., 147° E., while the *Adna* was in 36° 44′ N., 142° 58′ E., lowest pressure 29.42 inches. In the rough seas and in the dense fog which prevailed for a portion of the 7th and 8th, with her head to the storm, the *Adna* slowed engines for several hours. On the 8th the typhoon was reported central near 39° N., 150° E., moving northeastward.

On the 7th the British S. S. *Shabonee*, San Francisco toward Nagasaki, encountered fierce winds in this storm in 32° 48′ N., 144° 40′ E., highest force 11, from east by south, lowest pressure 29.04 inches. No information is at hand concerning the whereabouts of the typhoon on the 9th, but on the 10th it seems quite certain that it passed into the Aleutian region. The British S. S. *Empress of Canada*, bound toward Yokohama, at an early hour observed a southeast gale near 49° N., 168° E., with falling pressure. At 2 p. m. of the 10th, in 48° 50′ N., 165° 56′ E., the vessel experienced a west-northwest gale, force 8, and the lowest pressure reading for the month, 28.57 inches. To quote:

4 p. m., wind NW. x W., 8. Barometer 28.65. High, confused sea; overcast, squally. 8 p. m., wind NNW., 9. Barometer 29.02. Midnight, wind NNW., 8. Barometer 29.39. High NNW. sea. 10th, storm rapidly diminishing.

Early in May, in connection with the cyclonic conditions prevailing midway along the United States-Hawaiian routes, the Japanese S. S. *Azumasan Maru* on the 5th encountered an east gale of force 9, accompanied by a pressure lowest at 29.17 inches, in 45° 17′ N., 138° 50′ W. This storm, which merged with a disturbance of the Aleutian LOW type than prevailing south of Alaska, seems not to have been violent at any point. The LOW which engulfed it exhibited scarcely more energy, except that its minimum pressure was lower. On the 9th to 11th moderate gales were reported by several vessels within the area bounded by the 40th and 50th parallels, 142d and 152d meridians of west longitude. The Japanese S. S. *Arizona Maru* observed the lowest pressure, 28.80 inches, late on the 10th in latitude 50° 10′ N., longitude 147° 40′ W. On the morning of the 11th, slightly to the eastward, the same vessel noted the highest wind force, 9, from the southwest by south, observed in connection with this phase of the storm.

On the 23d the Aleutian LOW intensified somewhat to the southwestward of Alaska, and gales of force 8 were reported near 50° N., 175° W., by the British S. S. *Empress of Russia*, lowest pressure 29.58 inches.

On the 28th a storm developed off the Vancouver and northwestern Washington coasts, and caused gales to the southward and eastward. The highest wind velocity noted was observed by the North Head Weather Bureau station—56 miles an hour from the south. This was one of the few ocean storms to enter the North American mainland during May.

Pressure averaged normal or below over the eastern part of the ocean, as shown by observations at the island stations. This was the third month with an absence of pressure above normal but was distinguished from the preceding two by reason of the fact that the principal deficiency in May occurred at Midway Island, whereas in April it was at Honolulu and in March at Dutch Harbor. At the last-named station the average pressure, based on p. m. observations, was 29.83 inches, or practically normal. The highest pressure, 30.50 inches, occurred on the 2d; the lowest, 28.86, on the 13th. Absolute range, 1.64 inches. At Honolulu the mean p. m. pressure was 30.04, as compared with the normal of 30.05 inches. The highest pressure, 30.18, occurred on the 19th; the lowest, 29.94, on the 14th. At Midway Island the mean p. m. pressure (29 days) was 29.96 inches, or 0.13 inch below normal. The highest pressure, 30.16 inches, occurred on the 30th; the lowest, 29.74, on the 11th.

Fog was of widespread occurrence along the northern steamer routes, and was observed over some portion of the area on nearly every day of the month. It was observed along the American coast from Sitka to Cape San Lucas, and with especial frequency off San Francisco and Lower California.

NOTES.

Mr. A. W. Roebuck, third officer of the American oil tanker *E. L. Doheny III*, reported the following:

May 28.—10:30 a. m. Saw two exceptionally large waterspouts about a mile apart and moving from east toward west. Latitude 11° 42′ N., longitude 89° 10′ W.

Observer John H. Aspinwall, of the British S. S. *Canadian Transport*, Adelaide toward Vancouver, made the following comment:

May 12.—Picked up northeast trades about latitude 2° S., longitude 172° 24′ W. May 26. Lost them in latitude 34° N., longitude 146° W.

STORMY WEATHER OFF THE LOWER SOUTH AMERICAN COASTS.

By WILLIS E. HURD.

The British tanker *San Patricio*, Capt. A. Hulbert, Observer H. C. Archer, Buenos Aires toward San Francisco via Magellan Strait, encountered five days of stormy weather during May, 1923. The storm began at noon of the 6th with a moderate west-northwest gale near latitude 53° 50′ S., longitude 71° 30′ W. During the afternoon the wind increased to a strong gale, and by the 7th had become a whole gale, which continued with frequent violent rain squalls, accompanied by high, dangerous seas, until the 11th. The winds were from some westerly direction throughout. The pressure on the 8th dropped as low as 28.73 inches, in latitude 52° 55′ S., longitude 74° W. At 7 a. m. of the 11th in 47° 04′ S., 79° 40′ W., pressure had risen to 29.74 inches.

In connection with the foregoing, a report of a South Atlantic storm encountered by the British S. S. *Vestris*, Capt. Oscar Penrice, Observer A. G. T. Brown, Buenos Aires toward New York, is interesting. At 8 a. m. of May 12 the *Vestris* was in latitude 34° 53′ S., longitude 54° 28′ W. From 4 p. m. of that day until 8 a. m. of the 13th, when in 30° 44′ S., 49° 13′ W., the wind increased until it became a whole gale from the west-southwest, which continued until 4 p. m. of the 13th, after which wind and sea abated. The lowest observed pressure was 29.50 inches, in latitude 33° 42′ S., longitude 52° 52′ W., on the 12th.

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

ALFRED J. HENRY.

Clearly, the sluggish movement of cyclones and anticyclones was directly responsible for the character of the weather of the month—rather heavy and persistent rainy, cloudy weather in the Gulf States, Texas excepted, the lack of rainfall in the Lake region and thence eastward to New England, the cool weather east of the Mississippi, and other less striking phenomena. The usual details follow.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

The general types and movements of low-pressure areas were typical of the season, the erratic and sluggish tendencies continuing over from the preceding month. As usual there were frequent developments over the elevated regions of the West and the Canadian Northwest; but only a portion of these reached the migrating stage. The three storms which reached the Canadian Maritime Provinces originated over the Southern Plateau region; the remainder of the low-pressure areas noted slowly dissipated or were lost in secondary developments.

Of the eight high-pressure areas charted, four were of the Alberta type, two from Hudson Bay, and two were offshoots from the pressure maximum normally over the North Pacific Ocean at this time of the year. The relative numbers of these types are about normal.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

Free-air temperatures (Table 1) for the month averaged in general below normal. The departures decreased, however, with increasing altitude, becoming positive in the highest levels at most of the stations. On the 8th the lowest temperatures on record for the month of May in the upper levels were observed at Drexel and Ellendale and on the 9th at Due West, Groesbeck, and Royal Center.

The mean relative humidities were for the most part below normal, except at Due West and in the higher levels at Royal Center. The apparent general increase in the departures with increase in altitude is largely caused by the fewer observations at higher levels and the large fluctuations of this element.

The vapor-pressure departures were practically the same as those for temperature.

The resultant wind directions and velocities for the month are shown in Table 2. It will be observed that in general the resultant velocities for the month do not differ greatly from the normals. The resultant directions, however, vary considerably in many cases. For example, at Drexel where this difference is greatest the south component is much less than the normal. At Broken Arrow and Groesbeck this is also true, although to a lesser degree.

The following stations reported pronounced easterly winds at altitudes of 5,000 meters or higher:

Station.	Date.	Altitude (meters).	Average velocity.
			m. p. s.
Drexel, Nebr	28	Surface to 8,000	6
Due West, S. C	2	1,000 to 6,000	4-10
Do	22	Surface to 5,000	2
Do	31	Surface to 6,500	8
Ellendale, N. Dak.[1]	16	4,500 to 8,000	5-10
Lansing, Mich	3	Surface to 5,000	5
Do	24	Surface to 5,000	8-4
Do	28	Surface to 10,000	5
Do	30	Surface to 9,000	6
McCook Field, Ohio	2	Surface to 7,000	8
Madison, Wis	26	Surface to 7,000	5
Royal Center, Ind	2	Surface to 5,000	8-4
Do	3	Surface to 5,500	8-16
Do	5	Surface to 5,000	10
Do	24	Surface to 5,000	8-2
Do	27	Surface to 5,000	8
Do	28	Surface to 9,000	8

[1] Closely verified by double-theodolite observation immediately after.

Ellendale reported a wind of 42 m. p. s. from the north at 4,200 meters on the 8th. This occurred on the eastern side of a strong HIGH, centered at that time over western North and South Dakota. As would be expected from this great velocity and such conditions a rapid movement south-southeastward of this HIGH occurred during the next 24 hours. As a matter of interest it may be mentioned that the velocity and direction found at the 3,000-meter level (NNW.-24 m. p. s.) gave an exceedingly true indication of the place at which the center of the HIGH was found at the end of 24 hours by assuming this as the rate and direction of movement.

Another observation worthy of note was made at Ellendale on the morning of the 14th when the velocity from the surface to 5,000 meters increased slightly from 2 m. p. s. to 10 m. p. s. but sharply from 5,000 meters to 8,000 meters where a speed of 37 m. p. s. was recorded. This high upper wind, indicative of a marked low pressure over the polar regions, the latter being produced by the low temperatures in that region as shown on the weather map of that date, would seem to signify a rapid movement of pressure areas during the next immediate period. The map of the next day strikingly confirms this assumption.

A kite flight at Drexel on the 8th, made in the front of a strong HIGH, showed unseasonably low temperatures in the upper levels. Minimum temperatures records for this month for the past 8 years at levels between 750 meters and 3,000 meters were exceeded, the temperature at 3,000 meters being $-14.6°$ (C.), as compared with a normal of $1.1°$ (C.). This departure is exceptionally large considering this high elevation where temperatures are beyond the influence of diurnal variations. By the next day (9th) this HIGH had moved so that the center extended from the Drexel region south-southeastward to the Gulf. Ordinarily a kite flight in the center of a HIGH is not successful owing to the light surface winds and therefore inability to reach the more favorable winds existing aloft. However, by starting exceptionally early (5:30 a. m.) the Drexel station force fortunately obtained a flight on that date. The wind veered from WNW. at the surface to NW. and NNW. at 3,000 meters while the velocity increased from less

than 3 m. p. s. at the surface to 23 m. p. s. aloft. A temperature lapse rate, in general, less than the normal was found with inversions between 2,000 meters and 2,760 meters and between 3,100 meters and 3,300 meters. At Groesbeck, also under the influence of the HIGH center, conditions were more favorable and a good kite flight was readily obtained reaching to 4,000 meters. At this station temperatures at all levels were found to be considerably below their normals. The lapse rate from the surface to 1,000 meters was close to the monthly normal, an inversion extended from 1,000 meters to 1,500 meters, above which the lapse rate exceeded the normal appreciably.

In connection with the special forecast issued from the Central Office on the morning of the 2d to the Army aviators at Mitchel Field for their record making non-stop flight to San Diego, the free-air conditions showed the prevalence of easterly winds from the Atlantic coast westward to the Rocky Mountains. While the successful accomplishment of the flight has since shown that favorable or at least navigable conditions prevailed over the entire route the lack of definite free-air observations from the far western region is clearly evident.

From the 21st to the end of the month the eastern half of the country experienced stagnation conditions with respect to pressure areas. During this period easterly winds were found to high altitudes almost continuously and velocities were light as would be expected. These conditions proved suitable for a number of exceptionally long pilot balloon observations, among the highest of which was the one made at Lansing on the 28th. This reached 24,570 meters and was made with a single theodolite. Velocities were light practically throughout with a tendency to increase in the highest levels where 20 m. p. s. was observed. The direction was mostly easterly to 10,000 meters, where a veering to NW. and finally N. occurred.

TABLE 1.—*Free-air temperatures relative humidities and vapor pressures during May, 1923.*

TEMPERATURE (°C)

Altitude m. s. l. (meters).	Broken Arrow, Okla. (233 meters). Mean.	Departure from 5-year mean.	Drexel, Nebr. (396 meters). Mean.	Departure from 8-year mean.	Due West, S. C. (217 meters). Mean.	Departure from 3-year mean.	Ellendale, N Dak. (444 meters). Mean.	Departure from 6-year mean.	Groesbeck, Tex. (141 meters). Mean.	Departure from 5-year mean.	Royal Center, Ind. (225 meters). Mean.	Departure from 5-year mean.
Surface	18.3	−1.7	13.7	−2.5	19.3	−1.1	12.9	−0.6	23.1	+0.1	15.7	−1.4
250	18.2	−1.7			19.0	−1.0			22.0	−0.1	15.5	−1.3
500	16.7	−1.3	13.1	−2.4	16.8	−0.8	12.7	−0.5	20.0	−0.3	13.3	−1.0
750	15.3	−1.1	11.7	−2.1	15.2	−0.6	11.2	−0.4	18.3	−0.6	11.6	−0.9
1,000	14.1	−1.0	10.6	−1.8	14.0	−0.4	9.8	−0.4	16.8	−0.7	10.3	−0.7
1,250	13.2	−0.7	9.2	−1.8	12.7	−0.3	8.3	−0.4	15.8	−0.6	8.7	−0.8
1,500	11.9	−0.8	7.7	−1.8	11.3	−0.3	6.6	−0.6	15.2	−0.1	7.2	−0.9
2,000	9.3	−0.8	5.0	−1.8	8.6	−0.4	3.8	−0.5	13.1	+0.1	4.5	−1.1
2,500	6.7	−0.5	3.0	−1.1	6.1	−0.3	1.4	0.0	10.4	+0.1	1.5	−1.6
3,000	3.9	−0.2	0.8	−0.3	3.8	+0.2	−1.0	+0.4	7.6	+0.1	−1.8	−2.2
3,500	1.1	−0.2	−1.6	+0.2	1.4	+0.6	−3.4	+0.5	5.0	+0.6	−5.2	−2.8
4,000	−1.9	−0.2	−4.7	+0.1	−2.0	+0.2	−6.4	+0.4	2.4	+1.0	−8.1	−3.0
4,500			−7.4	+0.5	−5.6	−0.4	−9.2	+0.4	−0.1	+1.6		
5,000			−10.4	+0.9	−9.2	0.0	−11.8	−0.2	−2.8	+1.9		

RELATIVE HUMIDITY (PER CENT).

Altitude m. s. l. (meters).	Broken Arrow Mean.	Departure	Drexel Mean.	Departure	Due West Mean.	Departure	Ellendale Mean.	Departure	Groesbeck Mean.	Departure	Royal Center Mean.	Departure
Surface	73	−1	68	+2	71	+5	61	−2	66	−7	60	−2
250	73	−1			71	+5			68	−5	60	−2
500	72	−1	66	+1	72	+5	60	−2	70	−3	57	−5
750	71	−2	62	−2	73	+5	59	−1	70	−1	55	−6
1,000	69	−3	59	−4	71	+4	57	−3	68	−1	53	−7
1,250	65	−5	60	−3	70	+4	58	−3	64	−2	53	−6
1,500	64	−3	61	−2	69	+3	59	−2	57	−5	53	−5
2,000	62	−2	61	+1	66	+1	57	−3	52	−2	55	+1
2,500	59	−1	57	−1	64	0	52	−6	52	+2	56	+7
3,000	56	0	55	−3	61	+1	47	−10	55	+6	56	+11
3,500	54	+1	53	−5	61	+5	39	−13	48	+2	56	+13
4,000	42	−9	45	−12	63	+14	39	−12	47	+2	52	+12
4,500			46	−13	61	+18	40	−12	44	0		
5,000			48	−14	60	+17	39	−6	54	0		

VAPOR PRESSURE (mb).

Altitude m. s. l. (meters).	Broken Arrow Mean.	Departure	Drexel Mean.	Departure	Due West Mean.	Departure	Ellendale Mean.	Departure	Groesbeck Mean.	Departure	Royal Center Mean.	Departure
Surface	15.87	−1.67	11.26	−1.06	16.09	+0.11	9.50	−0.46	18.55	−1.75	10.76	−1.41
250	15.73	−1.66			15.84	+0.15			17.93	−1.50	10.55	−1.39
500	14.01	−1.34	10.50	−1.16	14.19	+0.38	9.32	−0.38	16.38	−1.12	8.80	−1.40
750	12.58	−1.19	8.98	−1.31	12.96	+0.38	8.17	−0.35	14.89	−0.81	7.52	−1.45
1,000	11.37	−1.15	8.05	−1.24	11.74	+0.25	7.34	−0.36	13.29	−0.78	6.64	−1.39
1,250	10.00	−1.26	7.44	−0.97	10.79	+0.35	6.70	−0.37	11.65	−0.70	5.94	−1.24
1,500	8.84	−0.96	6.96	−0.61	9.65	+0.21	6.10	−0.31	10.00	−0.75	5.33	−1.04
2,000	7.28	−0.52	5.86	−0.13	8.00	+0.19	4.78	−0.29	7.98	−0.06	4.42	−.49
2,500	5.84	−0.16	4.81	0.0	6.82	+0.27	3.58	−0.32	6.71	+0.38	3.36	−.22
3,000	4.61	+0.07	4.21	+0.28	5.78	+0.40	2.46	−0.58	5.91	+0.67	2.37	−.12
3,500	3.99	+0.20	3.62	+0.46	5.17	+0.70	1.42	−0.83	4.48	+0.34	1.63	−.23
4,000	2.81	−0.33	2.17	−0.36	4.51	+0.93	0.71	−0.97	3.69	+0.29	.55	−.57
4,500			2.03	−0.08	3.81	+1.07			3.03	+0.22		
5,000			1.94	+0.16	3.29	+0.98			3.01	+0.22		

TABLE 2.—*Free-air resultant winds (m. p. s.) during May, 1923.*

Altitude, m. s. l. (meters).	Broken Arrow, Okla. (233 meters). Mean. Dir.	Vel.	5-year mean. Dir.	Vel.	Drexel, Nebr. (396 meters). Mean. Dir.	Vel.	8-year mean. Dir.	Vel.	Due West, S. C. (217 meters). Mean. Dir.	Vel.	3-year mean. Dir.	Vel.
Surface	N. 85° E.	1.1	S. 25° E.	2.1	S. 73° E.	1.0	S. 3° E.	1.4	S. 75° E.	0.8	N. 73° E.	0.8
250	N. 87° E.	1.2	S. 26° E.	2.1					S. 77° E.	0.9	N. 72° E.	0.8
500	S. 56° E.	1.8	S. 20° E.	2.9	N. 88° E.	1.2	S. 1° E.	1.6	S. 70° E.	1.3	N. 66° E.	1.1
750	S. 35° E.	2.0	S. 8° E.	3.3	S. 82° E.	1.8	S. 1° W.	1.7	S. 43° E.	2.1	N. 75° E.	0.8
1,000	S. 9° E.	1.5	S. 6° W.	3.4	S. 84° E.	1.7	S. 20° W.	2.1	S. 29° E.	1.8	N. 51° E.	0.5
1,250	S. 10° W.	1.0	S. 23° W.	3.5	S. 84° E.	1.5	S. 30° W.	2.4	S. 13° W.	2.9	S. 49° W.	0.8
1,500	S. 49° W.	1.1	S. 33° W.	3.7	S. 88° E.	0.9	S. 41° W.	3.0	S. 41° W.	4.0	S. 45° W.	1.8
2,000	S. 87° W.	2.6	S. 52° W.	4.2	N. 3° W.	1.2	S. 59° W.	4.0	S. 56° W.	5.1	S. 64° W.	2.9
2,500	N. 64° W.	4.5	S. 73° W.	4.7	N. 28° W.	2.7	S. 70° W.	4.6	S. 69° W.	10.0	S. 74° W.	4.6
3,000	N. 58° W.	5.1	S. 88° W.	5.0	N. 54° W.	5.4	S. 77° W.	6.8	S. 78° W.	9.6	N. 82° W.	4.3
3,500	N. 67° W.	6.8	N. 75° W.	7.6	N. 58° W.	10.4	S. 84° W.	7.9	S. 85° W.	9.0	N. 74° W.	6.7
4,000	N. 28° W.	14.0	N. 44° W.	12.0	N. 64° W.	9.5	N. 84° W.	8.7	N. 66° W.	16.4	N. 54° W.	9.4
4,500	N. 45° W.	19.8	N. 45° W.	19.8	N. 68° W.	17.3	S. 75° W.	10.4	W.	18.6	N. 58° W.	9.7
5,000					N. 69° W.	19.9	N. 89° W.	16.6	W.	20.6	N. 74° W.	16.5

Altitude, m. s. l. (meters).	Ellendale, N. Dak. (444 meters). Mean. Dir.	Vel.	6-year mean. Dir.	Vel.	Groesbeck, Tex. (141 meters). Mean. Dir.	Vel.	5-year mean. Dir.	Vel.	Royal Center, Ind. (225 meters). Mean. Dir.	Vel.	5-year mean. Dir.	Vel.
Surface	S. 69° E.	0.6	S. 58° E.	0.6	S. 10° E.	1.6	S. 16° E.	1.9	N. 76° E.	2.2	N. 66° E.	1.2
250					S. 7° E.	1.9	S. 10° E.	2.4	N. 77° E.	2.3	N. 68° E.	1.2
500	S. 51° E.	1.2	S. 43° E.	0.8	S. 3° W.	2.4	S. 3° E.	3.6	N. 80° E.	2.6	N. 72° E.	1.0
750	S. 31° E.	2.3	S. 23° E.	1.4	S. 24° W.	2.8	S. 7° W.	4.1	N. 81° E.	2.4	N. 62° E.	0.7
1,000	S. 20° E.	2.7	S. 11° E.	1.7	S. 37° W.	4.0	S. 20° W.	4.7	N. 68° E.	1.9	N. 15° E.	0.5
1,250	S. 16° E.	2.8	S. 2° W.	2.1	S. 45° W.	4.8	S. 27° W.	5.0	N. 57° E.	1.6	N. 22° W.	1.0
1,500	S. 10° E.	3.1	S. 8° W.	2.6	S. 61° W.	4.5	S. 37° W.	5.0	N. 35° E.	0.9	N. 53° W.	1.1
2,000	S.	3.2	S. 22° W.	3.4	S. 78° W.	5.6	S. 48° W.	5.1	S. 8° W.	1.6	N. 80° W.	1.9
2,500	S. 4° W.	3.4	S. 29° W.	4.7	S. 86° W.	6.7	S. 64° W.	5.6	S. 31° W.	2.3	N. 80° W.	2.5
3,000	S. 3° W.	3.2	S. 38° W.	6.0	N. 83° W.	8.9	S. 75° W.	6.9	S. 66° W.	5.7	N. 77° W.	3.6
3,500	S.	4.5	S. 41° W.	5.4	N. 55° W.	8.5	S. 80° W.	7.6	S. 87° W.	6.3	N. 58° W.	4.8
4,000	S. 11° W.	7.1	S. 60° W.	5.9	N. 48° W.	12.5	N. 70° W.	11.6	S. 42° W.	6.2	N. 84° W.	5.9
4,500	S. 16° W.	12.0	S. 20° W.	2.8	N. 39° W.	11.7	N. 65° W.	12.9	S. 68° W.	14.4	N. 86° W.	5.0
5,000	S.	11.8	N. 73° E.	5.5	N. 74° W.	7.9	N. 88° W.	12.5				

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist, in Charge of Division.

PRESSURE AND WINDS.

Cyclonic and anticyclonic activity assumed the slowing-up process usual to the last spring month, and pressure variations were moderate, in the main. Despite this, however, the month as a whole presented some unusual aspects. Notable among these were the late and, in some localities, heavy snows about the 8th and 9th, over most central and northern districts from the Mississippi Valley eastward, being heavier in some places than at any time during the past winter, and severe cold and frost that immediately followed over portions of the same territory.

The movement of the cyclones across the country was likewise out of the ordinary, the paths assuming positions somewhat farther south than usual, resulting in unprecedented precipitation over portions of the Southeastern States, where May is frequently a comparatively dry month, and a decided lack of moisture over many north-central districts.

The principal cyclones attended by important precipitation, were as follows: From the 8th to 11th, when a storm of wide extent moved from the Great Lakes to the St. Lawrence Valley and New England, accompanied by widespread precipitation, mostly light, however, except in portions of the Atlantic coast region. This storm was notable for the extensive falls of snow which, in portions of the Ohio Valley and Great Lakes region, ranged up to 10 inches or more, with drifts from 2 to 4 feet in depth. (See pp. 260–262.) In many sections the falls were the greatest ever known so late in spring, while in others it was the first occurrence ever reported in May. Immediately following this, another storm developing in Kansas moved eastward during the 11th to 13th, attended by heavy rains in portions of the Ohio and middle Mississippi Valleys, and by lighter falls over adjacent regions.

The most widespread storm of the month, and probably the one giving the heaviest precipitation over extensive areas, moved from southern New Mexico to New England, from the 14th to 17th. This storm gave important rains over nearly all sections from the Rocky Mountains eastward, with heavy falls in much of the Mississippi Valley and Southeastern States and portions of the Southern Plains.

The latter part of the month had few well-developed cyclones, but pressure was frequently low over the Gulf States, and local thunderstorms, often accompanied by heavy rains, were of almost daily occurrence over many of the central and southern portions of the country from the Great Plains eastward.

The most important anticyclone of the month immediately followed the general storm of the 8th to 11th, and during its progress southeastward over the central valleys, about the 9th to 13th, was attended by severe frosts and temperatures frequently lower than ever before recorded so late in the season.

During the last decade of the month anticyclonic conditions prevailed almost continuously over the northern districts from the Great Lakes eastward.

For the month as a whole the pressure averages were above normal from the middle and northern Plains to the Great Lakes, and also in the far Northwest. Elsewhere they were below normal, and distinctly so over the Gulf and South Atlantic States.

Compared with the preceding month the pressure was lower in all districts save from the Great Lakes eastward and along the North Pacific coast. This distribution is not materially different from normal, save that the area of excess over the northeastern districts is materially greater than may usually be expected. On the other hand, the deficiency over the southern districts is distinctly larger than usual.

As the pressure distribution in the main lacked sharp gradients over extensive areas, there was a general absence of severe cyclonic winds. Local thunderstorms with attendant high winds were numerous, and tornadic winds of more or less severity occurred over limited areas, description of which will be found at the end of this section and elsewhere in the REVIEW.

The prevailing wind directions, shown on Chart VI, indicate widely divergent directions in near-by areas, as may usually be expected at this period of the year.

TEMPERATURE.

The first week of the month was mainly warm, although over the far western States the 1st and 2d were in many instances the coolest days of the month. The averages for the period were above normal over most northern and central districts from the Rocky Mountains eastward and also to westward of those mountains. In the Gulf and South Atlantic States and over the middle and Southern Plains the averages were usually slightly below normal. At the beginning of the second week, however, hopes of continued and much desired warmth, which had already been long delayed, were shattered by an anticyclone moving into the upper Missouri Valley and overspreading the districts to the southward and eastward. During the following few days a return to almost winter conditions existed over large areas in the central valleys and eastern districts. Snow varying in depth up to 10 inches or more occurred over portions of the Ohio Valley, Great Lakes and eastern districts; freezing weather extended over much of the northern half of the country from the Rocky Mountains eastward, many stations reporting the lowest temperatures ever observed so late in the season, and frost was observed as far south as the central portions of the Gulf States.

Despite the severity of the cold, so late in the season, no great damage appears to have resulted, due mainly to the generally backward state of vegetation.

The average temperature for the week ending May 15th was below normal over all parts of the country from the western slopes of the Rocky Mountains to the Atlantic coast, save along the immediate Rio Grande Valley. Over the interior and northern districts the averages were from 6° to 9° below normal. In the far western districts the week continued moderately warm.

The third week continued cool over nearly all interior and northern districts, but freezing weather was confined to the extreme northern border and to the more elevated portions of the western Great Plains and mountain districts. The latter portion of the month was mainly without important temperature changes, but it continued mostly cooler than normal over the central valleys and eastern districts until near the end when the highest temperatures of the month were reported from many portions of these areas. This period was mainly warmer than normal in the Rocky Mountain districts and over the Northern States between the mountains and the Great Lakes, the averages for the period ranging from

6° to 12° per day above normal over much of this area. West of the Rockies the temperatures during the latter part of the month were mainly below normal, with occasional freezing at the higher elevations.

Considering the month as a whole, the average temperatures did not depart greatly from the normal, despite the apparently continuous cold over most central and eastern districts. The coldest sections, compared with the normal, were mainly from the middle Plains eastward to the southern Appalachian Mountains, and in the region of the Lower Lakes, where the monthly means ranged from 2° to 4° below the normal. Over Texas and thence westward to the Pacific, and generally in the Mountain and Plateau districts, the average temperature for the month was slightly above normal.

The main warm periods of the month were near the end of the first decade from the Great Plains westward; about the early part of the third decade over portions of the Gulf States; and generally during the latter part of that decade over most central and northern districts from the Rocky Mountains eastward.

The lowest temperatures of the month were on the 1st and 2d in the far Southwest, and over the greater part of the remaining area of the country from about the 8th to 10th. In California, however, some of the lowest temperatures occurred on the last day of the month.

PRECIPITATION.

May was a month of scanty rainfall, in comparison with what is expected, over far more than half the country, but the southeastern portion had a marked excess. In Georgia and Florida, and westward to extreme eastern Texas, also in most of Arkansas and Tennessee, there was far more than the average quantity for May, the second half of the month being particularly rainy. Many stations received three times the normal rainfall, and a few as much as four times the normal. At Titusville, Fla., almost 20 inches fell during the month, and at Beaumont, Tex., 20.58 inches; of this latter total, almost exactly two-thirds (13.54 inches) fell within about three hours, during the forenoon of the 18th, resulting in floods and great damage (see pp. 263–264). On the whole, these rains in the southeastern districts were detrimental, but in Florida the dry condition that had prevailed so many months was thoroughly relieved.

Other parts of the country where there was more than the normal precipitation were southern Michigan, the lower Ohio Valley, the Great Plains from southern Oklahoma to southern South Dakota and eastern Wyoming, and some areas in the far Northwest.

In the western portions of Oklahoma and Kansas the May rains were of vast benefit in relieving the long-continued dryness; though in a few portions the falls were so excessive as to cause damaging floods.

From the northeastern part of South Carolina northward and northeastward there was a marked deficiency, especially near the coast from Chesapeake Bay to Cape Cod. A considerable number of stations here, with normal May falls of from 2½ to 4 inches, had this May less than an inch. Fortunately, the closing days of April had given abundant rainfall over most of this area, and as temperatures were low there was little harm from the dryness.

Upper Michigan, Wisconsin, Minnesota, nearly all parts of the Dakotas and Iowa, and the northern and western portions of Missouri received considerably less than the normal May precipitation, while the central Plateau region, the far Southwest, and nearly all portions of Texas had but a small part of the normal. Southern California had practically no rains, and, in spite of some showery days in the northern part of that State, hardly any stations had as much as their monthly normals.

SNOWFALL.

There was not much new snow in the western mountains during May, but the old snow seems to have melted no faster than usual at this season, and the prospects for summer stream-flow are, on the whole, fairly good.

East of the Rocky Mountains the most notable snowstorm of the month came about the 8th and 9th, especially affecting lower Michigan and Ohio, and the nearest portions of Wisconsin and Indiana, also considerable parts of West Virginia. The falls were remarkable for the time of year, and generally in the southern portion of the area affected, from Illinois to Virginia, it was the latest snowfall of record. At Lansing, Mich., the snowfall within 24 hours on the 8th and 9th was 11.5 inches.

RELATIVE HUMIDITY.

The percentage of this element of the weather was mainly deficient over the central and northern districts, due to a general lack of precipitation, despite the prevalence of cool weather which ordinarily tends to its increase. In the Southeastern States the percentages were mainly above normal due to the highly saturated condition resulting from frequent rains, and similar conditions prevailed, but to a less extent in the middle Plains. Elsewhere the relative humidity was mainly less than normal.

SEVERE LOCAL STORMS, MAY, 1923.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.]

Place.	Date.	Time.	Width of path (yards).	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
Wylie, Tex. (2½ miles northwest of).	1	2:30 p. m.				Tornado	Two homes destroyed	Dallas Morning News.
New Orleans, La., and vicinity.	1-2					Wind and rain	Some property damage and several persons injured. Street-car traffic halted on some lines and telephone service interrupted in various parts of the city.	Times-Picayune (New Orleans, La.); official, U. S. Weather Bureau.
Meridian, Miss	2	2 to 3 a. m.				...do	Wires broken, outbuildings and fences blown down and trees uprooted.	Official, U. S. Weather Bureau.
Alabama and Mississippi coasts.	2				$3,200	Wind	Dredge boat sunk at Fort Morgan and other damage at Pascagoula. Minor damage in Mobile.	Do.
Southeastern Hillsborough, northeastern Hardee, and southwestern Polk Counties, Fla.	3	9 to 11 a. m.		1	200,000	Wind, rain, hail	Several buildings razed; 12 persons injured; 1 cow and many chickens killed; poles blown down and crops destroyed. Path 65 miles long and greatest width 10 miles.	Do.
Keokuk, Iowa	11	p. m.				Thunderstorm and hail.	Trees broken, gutters overflowed, telegraph and telephone service interrupted.	Do.
Central Illinois	11					Wind	Damage to trees and farm properties	Do.
Neosho, Mo	11	p. m.			300,000	Wind, rain, and hail.	Property and crops damaged, also tree-fruits, and strawberries. Width of path 4½ miles, length 12 to 15 miles.	Do.
Davidson County, Tenn	12		50-200		65,000	Tornado	Several buildings demolished and others damaged. Considerable damage to Old Hickory powder plant; 6 persons injured. Path 10 miles long.	Do.
Pittsburgh, Pa	12	4 p. m.	1,320		20,000	...do	Considerable damage to roofs and a number of trees blown down. Path ¾ mile long.	Do.
Thrall, Tex	14	p. m.			600	...do	One house and barn destroyed. Trees twisted off.	Do.
Hot Springs, Ark	14	4 to 8 p. m.			1,000,000	Heavy rain	Heavy damage from floods and lightning	Do.
Little Rock, Ark. (west section of).	14	8 p. m.	300-930		40,000	Tornado	3 buildings practically destroyed; a few badly damaged. Telephone and lighting service cut off. Car service delayed 24 hours. Path 2 miles long.	Do.
Mitchell County, Tex	14	a. m.		21	500,000	...do	Many persons made homeless; heavy property damage. Path ½ to 2 miles wide and 30 miles long.	Houston Post; Times-Record (Fort Smith, Ark.).
Sevier County, Ark	14	p. m.	880			...do	Houses, barns, crops, and timber destroyed; 2 persons injured. Cotton crop severely damaged.	Official, U. S. Weather Bureau.
Byesville, Ohio	15	...do	50			...do	50 buildings blown down or unroofed; communication lines crippled; several persons injured.	Plain Dealer (Cleveland, Ohio).
Laurens and Abbeville Counties, Va.	15				20,000-40,000	Electrical and rain.	General damage done	Official, U. S. Weather Bureau.
Macon, Ga	15	3:06 to 3:45 p. m.				Thunderstorms	Trees down; lines of communication and lighting crippled; some damage to homes and office buildings.	Do.
Beaumont, Tex	18				500,000	Heavy rains	Merchants' losses heavy. Much damage by lightning.	Dallas Morning News.
Milwaukee, Wis. (north of, near Brown Deer).	19	p. m.			10,000	Wind	Many small buildings razed. Local damage slight.	Official, U. S. Weather Bureau.
Lodi, Wis., and vicinity	19	p. m.				...do	Farm buildings and orchards damaged	Wisconsin State Journal (Madison, Wis.).
Ottawa and Kent Counties, Mich. (portions of).	19	7 to 7:45 p. m.	100			Tornado	Considerable damage to property and trees. Path 18 to 20 miles long.	Official, U. S. Weather Bureau.
New Orleans, La	19				2,500	Wind	Miscellaneous damage	Do.
McLean, Tex	21	4:30 p. m.			8,000-10,000	Tornado	12 homes completely destroyed; crops swept away; live stock killed and maimed.	Wichita Beacon (Kansas).
Wichita, Kans., and vicinity	22	p. m.	1,760		100,000	...do	Heavy damage to buildings. Crop damage unestimated. In Clonmell 12 farmhouses were wrecked and practically every building damaged. Storm was accompanied by rain and hail; 5 persons injured.	Official, U. S. Weather Bureau.
Greensburg, Kans	22	6 p. m.			150,000	...do	Score of persons injured; 40 residences damaged; more than 100 persons homeless.	Official, U. S. Weather Bureau. Wichita Eagle.
Fort Smith, Ark	23	p. m.				Wind	Wires and trees blown down; public utilities companies suffer most.	Official, U. S. Weather Bureau.
Grant Township, Mahaska County, Iowa.	29	p. m.				Tornado	Oat field damaged	Do.
Lariat, Wyo. (50 miles southeast of Sheridan).	31	5 p. m.	100	1		Cyclone	Many homes razed; property damage unestimated.	Wyoming Tribune Leader (Cheyenne).
West shore of Mobile Bay	31	a. m.			2,000	Thunderstorm	Crops damaged considerably by hail	Official, U. S. Weather Bureau.
Dodge City, Kans. (6 miles southwest of).	31	p. m.				Tornado	Minor damage on farms	Do.

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

Storm warnings.—May was an unusually quiet month in the Washington Forecast District. No severe storms occurred on the Atlantic coast or the east Gulf coast; but southwest storm warnings were ordered displayed along the middle and north Atlantic coasts on three dates, namely, the 8th, 11th, and 15th. In each instance the highest velocity reported was 48 miles an hour at Atlantic City, N. J.

Frost warnings.—On a number of dates, mostly during the first three weeks of the month, frost warnings were issued for portions of the North Atlantic States and the lower Lake region, and occasionally for the Ohio Valley and portions of the Middle Atlantic States. On the 9th warnings were issued for the entire area from Maryland and the Ohio Valley southward as far as the northern portion of Mississippi, Alabama, Georgia, and South Carolina. All frost warnings were well verified, as a rule, except on two or three days. In addition to the more general warnings referred to, warnings of frost in the cranberry bogs of New Jersey were issued on 15 days during the month.

A special aviation forecast was issued on the morning of the 2d for the guidance of Lieutenants Kelley and MacReady, who made the first nonstop flight across the United States. They flew from Mitchell Field, Long Island, to San Diego, Calif., and it was essential that they should have easterly winds for a considerable portion of their journey. The forecast message was as follows:

WASHINGTON, D. C., *May 2, 1923.*

Lieut. O. G. KELLEY,
Mitchell Field, Mineola, Long Island, N. Y.

Generally fair weather next 48 hours, Mitchell Field to San Diego, except that there will be considerable cloudiness with a probability of local rains to-night or Thursday between Dayton and the Missouri-Kansas line. Moderate northeast and east winds Mitchell Field to Dayton, and moderate to fresh easterly Dayton to western Missouri. Gentle to moderate variable winds from Kansas to San Diego up to 5,000 feet.

(Signed) MITCHELL.

From press reports of the flight it appears that the forecast was verified in practically every detail.—*Chas. L. Mitchell.*

CHICAGO FORECAST DISTRICT.

The weather conditions in the Chicago Forecast District in the month of May were rather unusual. The temperature was somewhat above the seasonal normal in the Northwest, but in the Central Plains States, central valleys, and most of the Great Lakes region the temperature was below normal, and in the southern portion of the last-named district the readings were decidedly below, the departures ranging from 4° to more than 5° at some stations. This deficiency in temperature in the southern and eastern portions of the district was mainly due to the movement during the month of the storm centers somewhat to the south. But few centers passed across the more northerly States. Moreover, the distribution of rainfall was quite irregular, considerable excesses being registered at some points and deficiencies at others.

The first storm, which justified general storm warnings on the Great Lakes, appeared to be of little consequence as it approached the Lake region from the West until the morning of the 8th, when the center was over Lake Michigan. Storm warnings were ordered up at 9:30 a. m. on that day on the Upper Lakes, and on Lake Erie the morning of the 9th. These warnings were, for the most part, verified. Warnings of frost had been sent on the morning of the 7th to Minnesota, western Wisconsin, and the middle Plains States, and on the 8th warnings of frost or freezing temperature from the Missouri Valley eastward, the temperature then falling to freezing over a large area in the rear of the storm.

The storm which was approaching the southern Lake region from the Middle West on the 11th seemed to justify the ordering of warnings that night on Lakes Michigan, Huron, and western Erie, and the following morning on eastern Lake Erie and Lake Ontario, but this storm rapidly passed to the east without causing any strong winds.

Frost warnings, however, which were issued on the morning of the 12th to most of the eastern portion of the district were fully verified, frost occurring as far south as the Ohio Valley on the following morning.

The next storm gradually developed in the Southwest and moved northeastward toward the western Lake region, steadily developing in energy. Storm warnings were ordered on the morning of the 15th for all the Lakes except Superior. This storm seemed to lose energy as it passed farther eastward, but strong winds were registered at several stations, the highest velocity being 56 miles at Buffalo, N. Y., and 48 miles at Toledo, Ohio.

Frost warnings were issued on the morning of the 15th for the trans-Mississippi region as far as the Rockies, and on the morning of the 16th for the western Lake region and the upper Mississippi and lower Missouri Valleys; and frosts were later reported as forecast.

No other warnings of a general character were issued during the month. The spring season was so late over most of the district that the frosts which did occur caused but very little damage.

Special fire-weather forecasts were sent to Ely, Minn., beginning with the 17th. Because of the lack of rain in that area, forest fires had developed, and they were still burning at the close of the month.

A special forecast has been sent during the school year to the *Daily Cardinal*, the daily of the University of Wisconsin at Madison. Its discontinuance with the close of the school year was advised in the following complimentary letter from the editor:

This is to notify your office to discontinue the nightly weather forecast you have been furnishing *The Daily Cardinal* with your telegram of Saturday night, June 2.

* * * * *

In closing what little official correspondence I have carried on with your office, may I thank you once again for your courtesy in supplying *The Cardinal* with a nightly forecast. More or less an experiment with our paper in the first place, our weather reports have within the year grown to be one of our strongest features, and it is to your office, of course, that we feel most indebted for the success of the venture. Personally, I have only praise for the efficiency, courtesy, and regularity of the Chicago Weather Bureau.

Sincerely,

GEO. L. GEIGER (*Editor*).

—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Frost warnings were issued on May 15 for Oklahoma and the Texas Panhandle, and on the 16th for northern Arkansas. Frost temperatures occurred, but partly cloudy weather prevented frost to any material extent.

Alfalfa warnings were included in precipitation forecasts on several dates for Oklahoma.

Storm warnings were issued for the Texas coast on the 11th, 13th, and 21st. Small-craft warnings were displayed on the Louisiana coast on the 11th, 14th, and

15th, and on the Texas coast on the 30th. These warnings were justified by subsequent conditions, and no general storm occurred without warning.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

On the morning of the 1st, freezing weather in western Colorado, with temperatures as low as 22° in the elevated portions of northern Arizona and southern Utah attended an area of moderately high pressure whose crest was over the last-named State. A HIGH which moved with increasing intensity from the north Pacific coast on the 2d to South Dakota and Nebraska on the 4th was attended by light showers in eastern Colorado on the 3d and by killing frosts in the northeastern portion of this State on the morning of the 4th. Occasional showers in the northern portions of the district on the 5th, and also in Colorado on the 6th, attended a LOW which advanced northeastward from Arizona on those dates. The succeeding HIGH which overspread the northern Rocky Mountain States on the 6th and 7th was attended by freezing temperature in north-central Arizona on the 7th and 8th and by frosts in extreme northeastern Colorado on the 8th, when the crest of the HIGH was over the Dakotas. Showery conditions in northern Colorado on the 10th, 11th, and 12th, and in about all of the district on the 13th and 14th, resulted from two separate disturbances which advanced eastward from Arizona. Frost occurred in north-central Arizona, north-central New Mexico, and southeastern Colorado, and freezing temperatures in north-central Colorado on the 15th, followed by killing frosts and freezing temperatures in northeastern Colorado on the 16th, due to an area of high pressure which developed over the Northern Rocky Mountain States on the 14th and moved southeastward to western Kansas and northwestern Texas by the morning of the 16th. Low pressures prevailed in most of the Rocky Mountain region from the 16th to the 31st, with scattered showers and thunderstorms in Colorado and occasionally in Utah. During the 31st the Plateau LOW advanced with increasing intensity from Utah to southeastern Wyoming, where it recurved to the northwestward, its center on the following morning being over extreme northern Idaho. This unusual action of the disturbance was followed by a sharp fall in temperatures in extreme western Colorado, northern Arizona, and southern Utah, amounting to a local cold wave at Flagstaff, where the minimum temperature was 24°. The lowest temperature on record for the first decade in June, 22°, occurred at Modena.

Frost warnings were issued almost daily for some part of the district, especially the higher elevations, from the 1st to the 15th and again from the 21st to the end of the month.

As a rule the frost and freezing temperature warnings distributed were verified.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT.

No severe storms visited this district during the month. Storms moving southeastward from the north Pacific passed inland at a high latitude, and thence either eastward through Canada or southward along the western slope of the Rocky Mountains to Arizona and New Mexico and then east. On one or two occasions storms developed over the southern Plateau and moved eastward.

While the storms passed inland too far north to cause gales along the northern coast, they gave frequent showers in the North Pacific and Plateau States. The showers were generally light and in some instances were accompanied by thunderstorms. No damage was reported either from heavy rain or lightning.

No severe frosts occurred in the fruit centers, and the special fruit-frost service closed for the season in all portions of this district during the latter part of the month.

No storm warnings were issued during the month.

Live-stock warnings were issued in eastern Washington, eastern Oregon, and Idaho on the 25th. They were timely and verified.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

While nearly all the rivers east of the Mississippi River, except those of the Middle Atlantic system, were in flood at some time during the month of May, the floods were short and moderate for the most part, except in the Tombigbee River of Alabama, which, below the mouth of the Black Warrior River, had been in flood almost continuously since March 23, with a crest stage of 51.4 feet, or 12.4 feet above flood stage, on March 30. The highest stage reached in May was 47.2 feet on the 22d, and the river did not fall below the flood stage until June 6, another crest of 46.9 feet having been reached on June 3. Damage and loss amounted to about $16,000, while partial returns showed a saving of $10,700 through the warnings issued.

As the interval between the April and May floods in the Pearl River of Mississippi had been so short, farming and stock operations had not been undertaken, and there was therefore little or no damage done, but logging and sawmill operations continued inactive through virtually all of May and the losses were very heavy.

The floods in the Wabash and White Rivers of Indiana, while moderate, overflowed more than 5,000 acres of corn and wheat and caused losses in prospective crops of about $31,000, and other property losses of about $3,000. The value of property saved through the warnings was about $23,000. One life was lost near Prairietown, Ind.

The Yazoo River of Mississippi remained in flood throughout the month.

Warnings for all floods were issued at the proper time.

A severe flood occurred in the Ouachita River in Arkansas during the third week of the month. It was caused by a 48-hour rainfall of from 5 to 8 inches, and although warnings were issued as soon as information of the heavy rain was received, it was impossible in some localities to effect the entire removal of live stock and other portable property. At Arkadelphia, Ark., the Ouachita River rose from 2 to 23 feet during the 24 hours ending at 7 a. m. May 15. This crest stage of 23 feet was 5 feet above the flood stage and 0.4 foot above the previous high-water mark of May 12, 1920. At Camden, Ark., the crest stage on May 18 was 9.9 feet above the flood stage of 30 feet. Below Arkadelphia the rainfall was not so heavy, and flood stages were not reached south of the Arkansas-Louisiana boundary. One colored man was drowned, 2,000 acres of farm lands were overflowed, and 600 head of live stock were lost. Crop losses were about $50,000 and those of live stock $10,000, mostly in the vicinity of Arkadelphia. Below this place there was time after the receipt of the warnings to remove stock, etc., and no losses were reported.

Shortly after the middle of May a series of heavy rains set in over the Arkansas and Canadian River Valleys in eastern Colorado, Kansas, Arkansas, Oklahoma, and extreme northwest Texas, and within a few days the Arkansas River below Wichita, Kans., and all tributaries to the southward were in flood. The floods continued at the close of the month and became very dangerous and destructive during the first half of June. A description of these floods will appear in the MONTHLY WEATHER REVIEW for June, 1923.

Local floods in the rivers of Texas were unimportant.

The Solomon River of Kansas was in moderate flood above Niles, Kans., from May 24 to 27, inclusive, following a 48-hour rain of from 2.50 to 3.75 inches. At Beloit, Kans., the crest stage on May 25 was 28.8 feet, 10.8 feet above the flood stage, and at Niles, Kans., 24.4 feet on May 30, or 1.6 feet below the flood stage.

Warnings were issued as soon as possible, and losses and damage were limited to $17,500, of which $12,000 was in prospective crops. The losses were confined to Mitchell County, and the value of the property saved was $1,000.

Generous rains in western Nebraska brought the North Platte River at North Platte to the flood stage of 5 feet on May 29. The rise was devoid of special incident.

The rise in the upper Colorado River and tributaries in Colorado, Wyoming, and Utah began early in the month, and the first warnings were issued on May 4 for the North Fork of the Gunnison River of Colorado. The floods gradually extended throughout the main stream, although flood stage was not reached much below Parker, Ariz. Warnings of the flood progress were issued frequently and no damage was reported.

The Rio Grande was continuously in moderate flood in the vicinity of San Marcial, N. Mex., after May 6, with a crest stage of 2.1 feet, or 1.1 feet above flood stage, on May 15. Warnings were issued at various times and no damage was reported.

The annual rise of the Columbia River was in progress at the close of the month, the flood stage of 24 feet having been reached at Marcus, Wash., the outpost station, on May 27. The river was also in flood at Vancouver, Wash., on the following day, the flood waters overflowing into the Willamette River at the same time, bringing the latter to flood stage. Report on this flood will be made later.

Flood stages during May, 1923.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
ATLANTIC DRAINAGE.					
Connecticut:	*Feet.*			*Feet.*	
White River Junction, Vt	13	(1)	5	22.0	1
Hartford, Conn	16	(1)	6	20.4	2
Cape Fear:					
Elizabethtown, N. C	22	2	2	23.0	2
Santee:					
Rimini, S. C	12	9	12	12.9	12
Do	12	19	21	12.7	21
Do	12	25	(2)	13.3	29
Ferguson, S. C	12	10	14	12.3	12-13
Do	12	21	22	12.1	21
Do	12	27	(2)	12.8	30-31
Saluda:					
Pelzer, S. C	7	29	(2)	7.7	31
Broad:					
Carlton, Ga	11	29	(2)	17.0	31
Oconee:					
Milledgeville, Ga	22	6	7	29.0	6
Do	22	28	28	24.6	28
Do	22	31	(2)	25.2	31
Ocmulgee:					
Macon, Ga	18	27	28	20.6	27
Do	18	30	(2)	20.1	30
Abbeville, Ga	11	10	13	12.1	12
Do	11	23	24	11.4	23-24
Do	11	29	(2)	12.6	31

Flood stages during May, 1923—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
EAST GULF DRAINAGE.					
Apalachicola:	*Feet.*			*Feet.*	
River Junction, Fla	12	8	9	12.0	8-9
Do	12	19	20	12.5	19
Do	12	29	(2)	16.0	31
Cahaba:					
Centerville, Ala	25	16	16	27.0	16
Tombigbee:					
Lock No. 4, Ala	39	2	11	43.9	7-8
Do	39	17	[3]5	47.2	22
Pearl:					
Jackson, Miss	20	19	26	23.0	21
Do	20	29	29	20.1	29
Do	20	31	(2)	20.1	31
Columbia, Miss	18	27	(2)	20.5	28
West Pearl:					
Pearl River, La	13	(1)	5	14.4	2
Do	13	17	(2)	15.2	19
GREAT LAKES DRAINAGE.					
Maumee:					
Fort Wayne, Ind	15	15	18	17.4	17
Pine:					
Alma, Mich	7	17	18	7.7	17
Cass:					
Vassar, Mich	14	18	19	15.2	18
MISSISSIPPI DRAINAGE.					
Tuscarawas:					
Coshocton, Ohio	8	13	16	11.6	13
Walhonding:					
Walhonding, Ohio	8	13	13	12.3	13
Scioto:					
Larue, Ohio	11	13	14	13.5	13
Do	11	16	16	12.0	16
Prospect, Ohio	10	13	14	11.8	14
Olentangy:					
Delaware, Ohio	9	13	13	11.1	13
Wabash:					
Bluffton, Ind	12	15	15	12.0	15
La Fayette, Ind	11	14	20	17.7	17-18
Terre Haute, Ind	16	19	22	17.2	21
Vincennes, Ind	14	21	25	14.6	24
Mount Carmel, Ill	16	19	25	18.6	23
West Fork of White:					
Elliston, Ind	19	16	21	24.1	19
Edwardsport, Ind	10	16	24	17.3	20
Do	10	29	(2)	11.1	31
French Broad:					
Penrose, N. C	13	30	(2)	15.3	30
Asheville, N. C	4	29	31	5.0	29
Illinois:					
Peru, Ill	14	19	20	14.0	19-20
Henry, Ill	7	22	24	7.1	22-24
Beardstown, Ill	12	28	28	12.0	28
Do	12	30	30	12.0	30
St. Francis:					
Marked Tree, Ark	17	19	(2)	19.1	28-31
Arkansas:					
Fort Smith, Ark	22	24	30	26.1	25
Dardanelle, Ark	20	25	(2)	25.0	26
Little Rock, Ark	23	27	27	23.0	27
Pine Bluff, Ark	25	28	(2)	25.6	29
Neosho:					
Yonkers, Okla	14	26	27	20.1	27
North Canadian:					
Woodward, Okla	3	16	16	3.3	16
Do	3	22	26	7.7	23
Do	3	30	30	3.2	30
Canton, Okla	4	22	25	6.7	24
Oklahoma City, Okla	12	22	22	12.1	22
Do	12	27	(2)	15.9	28
Petit Jean:					
Danville, Ark	20	(1)	1	21.2	1
Do	20	15	19	24.9	16
Do	20	24	29	23.1	26
White:					
Calico Rock, Ark	18	16	17	18.1	16
Do	18	26	26	18.7	26
Batesville, Ark	23	15	18	25.6	15
Do	23	26	28	27.0	26-27
Newport, Ark	26	17	22	28.7	19
Do	26	26	(2)	29.0	28
Georgetown, Ark	22	18	(2)	25.9	31
Clarendon, Ark	30	30	(2)	30.1	31
Black:					
Black Rock, Ark	14	6	(2)	24.3	16
Cache:					
Patterson, Ark	9	15	(2)	10.7	26-28
Yazoo:					
Yazoo City, Miss	25	(1)	(2)	30.1	1
Tallahatchie:					
Swan Lake, Miss	25	(1)	(2)	29.0	26
Sulphur:					
Ringo Crossing, Tex	20	5	5	21.2	5
Ouachita:					
Arkadelphia, Ark	18	15	16	23.0	15
Camden, Ark	30	18	23	39.9	18

[1] Continued from April. [2] Continued into June. [3] June.

Flood stages during May, 1923—Continued.

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
MISSISSIPPI DRAINAGE—continued.					
Atchafalaya:	*Feet.*			*Feet.*	
Melville, La.	37	(1)	1	37.0	1
North Platte:					
North Platte, Nebr.	5	29	29	5.0	29
Solomon:					
Beloit, Kans.	18	24	27	28.8	25
Trinity:					
Dallas, Tex.	25	(1)	5	31.0	3
Trinidad, Tex.	28	(1)	9	33.0	1
Liberty, Tex.	25	6	6	25.0	6
Colorado (Texas):					
Columbus, Tex.	28	2	2	28.0	2
Rio Grande:					
San Marcial, N. Mex.	1	7	19	2.1	15
Do.	1	21	(2)	1.7	31
Colorado:					
State Bridge, Colo.	9	25	(2)	10.7	28
Fruita, Colo.	12	29	29	12.3	29
Lees Ferry, Ariz.	12	7	(2)	17.3	31
Topock, Ariz.	14	15	18	15.0	17
Do.	14	27	28	14.2	28
Do.	14	31	(2)	14.3	31
Parker, Ariz.	7	11	(2)	9.1	28–29, 31
North Fork of Gunnison:					
Paonia, Colo.	9	8	12	9.4	10–11
Do.	9	21	22	9.0	21–22
Do.	9	26	28	9.0	26–28
Green:					
Elgin, Utah.	12	27	(2)	13.0	31
PACIFIC DRAINAGE.					
Kings:					
Piedra, Calif.	12	16	17	12.3	16
Columbia:					
Marcus, Wash.	24	27	(2)	24.4	30–31
Vancouver, Wash.	15	28	(2)	16.7	30
Willamette:					
Portland, Oreg.	15	29	(2)	16.0	31

[1] Continued from April. [2] Continued into June.

MEAN LAKE LEVELS DURING MAY, 1923.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., June 11, 1923.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during May, 1923:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.65	579.60	571.87	245.62
Above or below—				
Mean stage of April, 1923	+0.26	+0.42	+0.56	+0.29
Mean stage of May, 1922	−0.27	−0.80	−0.87	−0.93
Average stage for May, last 10 years	−0.49	−1.13	−0.97	−1.07
Highest recorded May stage	−1.40	−3.92	−2.55	−3.33
Lowest recorded May stage	+0.83	+0.04	+0.56	+0.66
Average relation of the May level to:				
April level	....	+0.30	+0.40	+0.30
June level	....	−0.20	−0.20	−0.20

[1] Lake St. Clair's level: In May, 574.55 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MAY, 1923.

By J. B. KINCER, Meteorologist.

There was entirely too much rainfall for agricultural interests during the month in the Southern States from the Mississippi River eastward, and rain was heavy to excessive in the west-central Great Plains. It was deficient in the middle Atlantic coast area and much of the Northeast, and there was less than the normal amount in nearly all sections west of the Rocky Mountains. Unusually heavy snow for the season fell in southern Michigan and in some adjoining sections of Indiana and Ohio, more than 10 inches being reported from some stations in Michigan. The month as a whole averaged cool for the season in the central Plains and generally so east of the Mississippi River, but elsewhere the monthly mean temperatures were near normal.

Winter wheat made fairly good progress during the month throughout the principal producing sections. The crop made some improvement in the Ohio Valley States, but continued in poor condition in some localities, especially in parts of Ohio and Indiana. Progress was satisfactory in the trans-Mississippi States, although the crop was very late and threatened with weeds in western Kansas, because of the frequent heavy rainfall following the long drought, with resultant thin stands. The month was generally favorable in the Spring Wheat Belt and that crop was reported as growing nicely in most sections, except in Iowa, where it was in only fair condition. Wheat came up to a good stand and was of good color in North Dakota and in satisfactory condition in Montana.

Oats were short and needed more moisture in Iowa, but the crop improved during the month in the Ohio Valley area, although it was too dry in parts of Illinois. Warmer weather and more sunshine were needed for corn in much of the interior of the country. Germination was slow and much replanting was necessary in Iowa and Kentucky, where planting was considerably delayed; the warmer weather near the close of the month, however, improved conditions in the eastern portion of the Corn Belt. Planting was hindered by wet soil in the central Great Plains, and there was considerable damage by heavy, washing rains on bottomlands in Oklahoma the latter part of the month.

The weather was unfavorable for cotton. Heavy and persistent rains fell in the eastern portion of the belt, where the excessive moisture and cool weather retarded germination and growth, and greatly interfered with cultivation. Much of the month was too cloudy, cool, and wet also in the northwestern portion of the belt, but conditions were more favorable in Texas, where cotton made fair to very good progress. The weather was more favorable also in the Carolinas, where field work as a rule made very good progress, but growth of cotton was rather slow because of the cool weather.

Pastures were short in the Central States east of the Mississippi River, although they showed improvement in most sections, while moisture was insufficient from the upper Mississippi Valley eastward. Ranges showed marked improvement in the Great Plains States and the central Rocky Mountain districts, where moisture was sufficient; stock did well in these areas. The range was variable, however, in the Southwest, and was mostly poor to only fair in New Mexico, with about the normal seasonal deterioration in Arizona. Ranges, pastures, and stock did well in the more northwestern States.

A cool wave overspread the Central and Northern States about the close of the first decade of the month, with freezing weather extending southward to southwest Virginia and to the Ohio River. Fruits escaped damage largely from frost although some early varieties were injured to some extent over a wide area from the upper Great Plains eastward. There was also some local frost damage in the more western States. Otherwise the month was generally favorable for fruit.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the lollowing table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1923.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	69.4	−2.0	Selma	94	23	Valley Head	31	9	8.59	+4.54	Thomasville	16.71	Troy	4.60
Arizona	68.1	+2.7	3 stations	110	[2] 9	Chin Lee	19	2	0.18	−0.12	Paradise	0.85	32 stations	0.00
Arkansas	67.2	−2.0	Malvern	98	20	2 stations	27	9	8.24	+3.12	Hot Springs	14.26	Magnolia	3.55
California	61.5	+0.1	2 stations	111	8	Summit	20	31	0.35	−0.74	Crescent City	4.12	64 stations	0.00
Colorado	51.4	+0.2	Lamar	95	10	Longs Peak	12	16	2.35	+0.36	Yuma	8.03	Yampa	T.
Florida	74.3	−1.6	Palatka	97	25	2 stations	39	10	9.01	+5.01	Titusville	19.93	Sand Key	3.53
Georgia	69.1	−2.9	2 stations	93	[2] 13	Blue Ridge	30	10	8.79	+5.40	Gillsville	13.78	Valdosta	4.31
Hawaii	72.1	+0.3	Mahukona	93	14	Volcano Observatory	47	1	3.46	−2.53	Glenwood	20.55	16 stations	0.00
Idaho	54.0	+0.4	Murphy	93	8	Warren	10	6	1.94	+0.11	Grangeville	4.64	Glenns Ferry	0.40
Illinois	60.9	−1.8	Danville	90	31	Ottawa	26	10	4.33	+0.10	Du Quoin	7.63	Marengo	1.02
Indiana	60.9	−1.4	Crawfordsville	95	31	2 stations	26	10	5.15	+1.03	Frankfort	10.71	Farmland	2.50
Iowa	59.6	−0.9	Pocahontas	90	6	Britt	20	9	2.84	−1.73	Alta	6.55	Mount Pleasant	1.07
Kansas	61.3	−2.0	Richfield	94	10	2 stations	25	9	5.75	+1.96	St. Francis	11.31	Kansas City	2.25
Kentucky	63.9	−1.7	2 stations	91	31	Farmers	27	10	3.98	+0.03	Lone Oak	9.55	Cynthiana	1.45
Louisiana	72.5	−1.3	Jeanerette	97	24	Minden	38	9	8.00	+3.67	Clinton	18.32	Plain Dealing	3.53
Maryland-Delaware	61.2	−1.7	Boyds, Md	94	29	Grantsville, Md	23	10	1.88	−1.70	Emmitsburg, Md	4.73	Dover, Del	0.63
Michigan	52.2	−1.3	2 stations	90	31	2 stations	15	13	2.98	−0.28	Millington	5.75	Monising	0.40
Minnesota	56.0	+1.2	Grand Rapids	91	28	Centerville	16	13	1.94	−1.40	Milan	4.18	Baudette	0.26
Mississippi	70.1	−1.6	2 stations	97	31	3 stations	38	10	9.09	+4.63	Waynesboro	15.45	Fayette	4.33
Missouri	62.7	−1.9	Caruthersville	97	31	Dean	25	9	4.59	−0.49	Jackson	11.31	Kidder	1.39
Montana	51.8	+0.5	Glasgow	96	26	Wisdom	9	9	2.14	−0.22	Adel	5.99	Knowlton	0.65
Nebraska	57.4	−1.7	3 stations	89	[2] 6	Fort Robinson	20	15	4.98	+1.36	Brewster	11.77	Springfield	1.97
Nevada	57.0	+1.4	Pahrump	103	9	2 stations	19	[2] 1	1.08	+0.21	Lamcille	4.45	3 stations	0.00
New England	53.6	−1.0	4 stations	89	26	Van Buren, Me	26	12	1.83	−1.58	Somerset, Vt	3.55	Nantucket, Mass	0.37
New Jersey	59.1	−1.3	....do	90	[2] 26	Layton	25	11	1.66	−2.08	Newark	3.62	Pleasantville	0.67
New Mexico	60.3	+0.9	Jal	99	20	Rociada	18	1	0.45	−0.53	Campana	2.90	19 stations	0.00
New York	53.4	−2.7	2 stations	90	[2] 25	North Lake	15	11	2.59	−1.09	Hoffmeister	4.67	Lauterbrunnen	0.56
North Carolina	64.8	−2.0	....do	90	[2] 7	Parker	25	9	4.32	+0.20	Highlands	14.95	Manteo	0.18
North Dakota	54.1	+1.5	New Salem	100	26	Pembina	13	12	1.77	−0.78	Larimore	4.63	Parshall	0.03
Ohio	58.3	−2.4	Clarington	96	31	Hiram	24	10	3.56	+0.04	Marion	6.03	Fernbank	1.90
Oklahoma	67.0	−0.7	2 stations	102	[2] 11	2 stations	30	9	6.63	+1.58	Holdenville	13.66	Goodwell	1.34
Oregon	54.3	+0.8	Richland	95	8	Crater Lake	9	7	1.96	−0.07	Classic Lake	6.27	Mikkalo	0.28
Pennsylvania	58.3	−1.7	Jersey Shore	95	29	West Bingham	20	[2] 3	3.50	−0.37	Center Hall	7.43	Philadelphia	1.23
Porto Rico	77.2	0.0	Utuado	99	11	Aibonito	54	8	2.78	−3.90	Utuado	12.20	Cayey	0.30
South Carolina	68.0	−3.1	Blackville	94	14	Walhalla	31	10	6.44	+2.78	Landrum	13.45	Camden	2.32
South Dakota	55.4	+0.6	2 stations	94	[2] 26	St. Francis	14	[2] 8	2.40	−0.67	Tyndall	7.38	Pine Ridge	0.35
Tennessee	65.2	−2.1	....do	90	[2] 20	Rugby	29	10	6.32	+2.34	Henderson	15.39	Bluff City	2.81
Texas	74.0	+1.0	Encinal	108	[2] 14	Denton	35	9	1.97	−1.71	Beaumont	20.58	8 stations	0.00
Utah	56.5	+1.6	Springdale	100	5	2 stations	10	1	1.19	−0.08	Hole-in-the-Rock	3.10	2 stations	0.00
Virginia	62.3	−2.1	Buchanan	94	28	Burkes Garden	25	9	1.91	−2.00	Dante	4.63	Woodstock	0.54
Washington	54.7	+0.4	Wahluke	94	8	Paradise Inn	14	2	1.85	−0.19	Paradise Inn	10.65	Cowiche	0.09
West Virginia	59.7	−2.2	Glenville	93	[2] 28	Beckley	21	10	2.58	−1.30	Gary	5.33	Wardensville	0.18
Wisconsin	54.9	+0.1	2 stations	90	[2] 28	Long Lake	17	13	2.07	−1.91	Danbury	3.45	Plum Island	0.95
Wyoming	50.2	+1 1	Colony	91	26	Big Creek	11	8	2.10	−0.01	Chugwater	5.26	Powell	T.

[1] For description of tables and charts, see REVIEW, July, 1922, pp. 384–385.

[2] Other dates also.

TABLE I.—*Climatologial data for Weather Bureau stations, May, 1923.*

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01, or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
New England.							**53.7**	**−0.9**										**72**	**1.47**	**−1.9**										**4.6**		
Eastport	76	67	85	29.84	29.92	−.04	46.8	−0.9	77	25	55	32	3	38	36	43	40	81	1.52	−2.3	10	6,998	s.	32	ne.	3	7	7	17	6.8	0.0	0.0
Greenville, Me	1,070	6	....	28.78	29.94	......	48.6	......	78	8	60	29	7	38	45	....	....	....	2.50	......	13	......	ne.	....	......	....	8	8	15	....	1.2	0.0
Portland, Me	103	82	117	29.84	29.96	−.01	53.3	0.0	84	25	62	35	11	45	31	47	41	68	1.97	−1.7	13	6,519	s.	36	se.	9	12	11	8	5.0	0.0	0.0
Concord	288	70	79	29.63	29.94	−.04	54.2	−0.1	87	26	67	34	11	41	39	....	....	....	1.47	−1.8	9	3,840	n.	24	w.	17	8	5	18	4.0	0.0	0.0
Burlington	404	11	48	29.51	29.95	−.02	51.6	−2.3	79	25	63	29	11	41	37	....	....	....	2.38	−0.4	11	7,184	n.	48	sw.	21	12	8	11	5.0	T.	0.0
Northfield	876	12	60	29.01	29.96	−.01	49.1	−4.3	80	26	63	26	11	35	44	47	44	78	1.75	−1.0	10	5,980	s.	29	sw.	10	13	9	9	5.0	5.0	0.0
Boston	125	115	88	29.81	29.95	−.03	57.6	+0.5	89	26	66	35	11	49	30	50	44	63	0.83	−2.7	7	7,261	w.	32	s.	9	13	11	7	4.8	0.0	0.0
Nantucket	12	14	90	29.94	29.95	−.05	52.0	−1.0	70	26	59	37	11	45	22	48	45	82	0.37	−2.3	6	11,551	sw.	42	sw.	10	18	5	8	4.3	0.0	0.0
Block Island	26	11	46	29.92	29.95	−.04	52.4	−0.4	70	26	59	38	11	45	23	48	46	85	0.41	−3.3	5	11,161	sw.	41	sw.	10	19	6	6	3.5	0.0	0.0
Providence	160	215	251	29.78	29.95	−.03	57.6	−0.9	88	26	68	34	11	48	31	50	44	64	1.19	−2.3	7	8,810	s.	43	s.	9	17	7	7	4.5	0.0	0.0
Hartford	159	122	140	29.77	29.95	−.03	58.0	−0.5	87	26	69	34	11	47	36	50	44	64	2.33	−1.2	7	5,900	s.	31	sw.	10	16	7	8	4.5	T.	0.0
New Haven	106	74	153	29.84	29.96	−.03	57.6	−0.3	89	26	67	34	11	48	35	51	45	67	1.94	−1.7	7	6,760	sw.	33	sw.	16	19	6	6	3.3	0.0	0.0
Middle Atlantic States.							**60.6**	**−1.4**										**66**	**1.98**	**−1.5**										**4.3**		
Albany	97	102	115	29.85	29.95	−.03	57.0	−2.3	89	26	69	33	11	45	39	49	41	58	1.65	−1.3	9	6,099	s.	38	sw.	15	21	4	6	3.1	T.	0.0
Binghamton	871	10	84	29.02	29.95	−.03	55.4	−1.6	83	26	68	32	11	42	44	....	....	....	3.17	+0.1	8	4,625	nw.	29	sw.	11	17	6	8	4.0	T.	0.0
New York	314	414	454	29.62	29.96	−.03	59.3	−1.3	81	26	68	38	10	51	28	52	47	71	1.58	−1.6	6	12,009	s.	48	sw.	12	17	8	6	4.1	0.0	0.0
Harrisburg	374	94	104	29.57	29.96	−.02	61.7	0.0	84	29	73	34	9	50	32	51	42	54	3.14	−0.5	9	5,090	ne.	44	sw.	9	13	10	8	4.8	T.	0.0
Philadelphia	114	123	190	29.84	29.97	−.02	62.6	−0.3	87	29	73	38	10	52	30	53	46	60	1.23	−2.0	7	7,546	s.	40	sw.	8	13	10	8	4.5	0.0	0.0
Reading	325	81	98	29.60	29.95	......	61.6	......	86	29	72	38	10	51	32	53	47	63	2.43	−0.9	9	3,652	se.	24	nw.	17	16	12	3	3.2	T.	0.0
Scranton	805	111	119	29.10	29.96	−.02	58.1	−0.7	86	26	70	32	11	46	39	52	46	67	3.26	−0.2	8	5,598	nw.	35	sw.	16	17	6	8	4.5	1.0	0.0
Atlantic City	52	37	172	29.91	29.97	−.01	56.9	−1.2	74	29	62	40	10	51	22	53	50	80	1.08	−1.9	5	12,638	s.	50	sw.	16	16	8	7	3.9	0.0	0.0
Cape May	18	13	49	29.98	30.00	+.01	58.4	−0.2	80	27	66	42	10	51	24	53	50	78	1.13	−1.9	3	6,428	s.	27	se.	20	16	7	8	4.0	0.0	0.0
Sandy Hook	22	10	55	29.93	29.95	......	58.0	......	82	26	66	40	10	50	25	51	47	72	1.32	......	6	9,996	s.	43	s.	16	17	8	6	3.6	0.0	0.0
Trenton	190	159	183	29.75	29.95	......	60.6	......	86	29	72	37	10	49	33	52	46	64	0.89	−2.6	7	8,378	sw.	42	sw.	16	15	7	9	4.3	0.0	0.0
Baltimore	123	100	113	29.82	29.95	−.04	63.8	−0.6	90	29	74	38	10	54	32	55	48	59	2.59	−1.0	9	4,890	s.	27	s.	8	13	10	8	4.4	T.	0.0
Washington	112	62	85	29.83	29.95	−.05	63.4	−0.3	88	29	75	37	10	52	33	55	47	59	1.50	−2.3	9	4,777	s.	28	nw.	9	15	10	6	4.2	T.	0.0
Lynchburg	681	153	188	29.22	29.96	−.04	63.8	−3.5	87	29	76	35	10	52	37	56	50	65	1.66	−2.3	8	4,977	e.	37	w.	9	11	10	10	5.5	T.	0.0
Norfolk	91	170	205	29.88	29.98	−.02	65.6	−0.6	84	27	75	42	10	56	29	57	52	68	1.90	+2.2	8	9,455	ne.	49	sw.	12	12	10	9	4.9	0.0	0.0
Richmond	144	11	52	29.81	29.96	−.03	64.4	−2.9	85	29	76	35	10	53	35	56	50	63	1.16	−2.7	7	6,072	se.	42	sw.	12	13	12	6	4.5	0.0	0.0
Wytheville	2,304	49	55	27.61	29.95	−.04	58.0	−3.4	79	19	69	32	10	47	37	53	48	72	3.27	−0.6	14	4,412	w.	36	w.	12	8	15	8	5.2	T.	0.0
South Atlantic States.							**68.2**	**−2.2**										**74**	**4.58**	**+0.8**										**6.2**		
Asheville	2,255	70	84	27.63	29.95	−.04	60.7	−1.9	80	19	70	35	9	52	35	54	50	72	5.71	+2.1	14	6,201	se.	36	nw.	8	6	11	14	6.3	T.	0.0
Charlotte	779	55	62	29.12	29.95	−.04	66.2	−2.7	87	19	75	40	9	57	32	59	54	68	4.01	+0.1	12	3,639	ne.	22	nw.	9	6	7	18	6.7	0.0	0.0
Hatteras	11	11	50	29.95	29.96	−.05	67.6	−1.1	80	28	73	50	10	62	17	62	59	75	4.13	0.0	7	8,435	ne.	45	nw.	9	10	13	8	5.1	0.0	0.0
Manteo	12	5	42																													
Raleigh	376	103	110	29.56	29.95	−.04	67.0	−1.1	86	19	77	41	10	57	29	59	53	65	1.09	−3.8	5	6,089	sw.	37	sw.	12	8	12	11	5.6	0.0	0.0
Wilmington	78	81	91	29.89	29.97	−.04	68.2	−2.6	82	15	76	44	10	60	23	63	60	77	1.32	−2.7	6	6,354	sw.	32	sw.	16	13	11	7	4.4	0.0	0.0
Charleston	48	11	92	29.90	29.95	−.06	70.7	−2.0	81	1	76	49	10	65	20	65	62	76	6.30	+2.8	14	8,425	e.	37	e.	4	6	7	18	6.9	0.0	0.0
Columbia, S. C	351	41	57	29.58	29.95	−.05	69.1	−2.7	87	14	78	42	10	60	32	62	59	77	2.97	−0.2	11	4,929	ne.	30	sw.	15	7	6	18	6.5	0.0	0.0
Due West	711	10	55	29.20	29.96	......	66.2	......	84	15	75	37	10	57	33	....	....	....	7.77	......	19	6,642	ne.	43	sw.	15	3	11	17	7.1	0.0	0.0
Greenville, S. C	1,039	113	122	28.85	29.93	......	65.0	......	84	22	73	40	9	57	31	59	54	74	5.79	......	16	6,924	ne.	38	w.	9	6	8	17	6.5	0.0	0.0
Augusta	180	62	77	29.74	29.93	−.06	69.5	−2.9	88	14	78	44	10	60	32	63	59	75	6.01	+2.8	15	3,245	e.	18	se.	28	5	8	18	6.9	0.0	0.0
Savannah	65	150	194	29.87	29.94	−.06	71.1	−2.3	86	29	78	47	10	64	23	65	62	78	5.52	+2.5	15	8,490	s.	43	nw.	9	8	7	16	6.2	0.0	0.0
Jacksonville	43	209	245	29.88	29.93	−.07	72.3	−2.7	88	23	79	51	10	65	21	66	64	81	8.73	+4.5	20	7,983	se.	43	s.	14	6	14	11	6.3	0.0	0.0
Florida Peninsula.							**76.6**	**−1.5**										**76**	**7.58**	**+3.4**										**4.6**		
Key West	22	10	64	29.89	29.91	−.06	78.8	−0.3	88	3	84	66	4	74	18	72	70	75	5.67	+2.3	9	7,637	se.	36	sw.	16	15	13	3	3.6	0.0	0.0
Miami	25	71	79	29.92	29.95	......	76.0	−2.6	88	30	82	57	10	70	23	70	68	75	11.48	+5.1	13	6,138	se.	29	sw.	5	5	19	7	5.6	0.0	0.0
Sand Key	23	39	72	29.90	29.93	−.04	77.2	......	85	25	80	65	4	75	14	73	71	79	3.53	......	6	8,886	se.	50	s.	16	15	13	3	3.8	0.0	0.0
Tampa	35	79	87	29.89	29.92	−.07	74.9	−1.5	88	1	83	55	11	67	23	69	66	77	5.59	+2.7	14	4,788	w.	26	ne.	3	6	17	8	5.5	0.0	0.0
East Gulf States.							**70.3**	**−2.0**										**79**	**8.60**	**+5.1**										**5.9**		
Atlanta	1,174	190	216	28.70	29.93	−.06	65.8	−4.1	83	22	74	40	9	58	26	60	57	79	9.83	+6.7	19	8,493	se.	50	nw.	15	7	4	20	7.2	0.0	0.0
Macon	370	78	87	29.53	29.92	−.07	69.2	−1.9	86	23	78	45	9	60	32	63	59	76	11.21	+8.3	15	4,671	e.	36	nw.	8	4	8	19	7.2	0.0	0.0
Thomasville	273	49	58	29.62	29.91	−.08	72.2	−1.8	88	18	81	46	10	63	30	65	62	77	6.00	+2.0	17	2,955	e.	22	sw.	15	4	10	17	7.2	0.0	0.0
Apalachicola	36	42	49	29.86	29.90	......	72.5	......	84	30	78	51	10	66	19	68	66	81	6.09	......	10	5,696	s.	38	ne.	24	10	14	7	4.5	0.0	0.0
Pensacola	56	149	185	29.84	29.90	−.09	71.4	−2.5	85	24	77	52	10	66	19	68	66	84	7.70	+5.0	17	9,924	s.	60	sw.	15	10	12	9	5.5	0.0	0.0
Anniston	741	9	57	29.13	29.91	−.08	67.4	−1.0	87	22	78	35	10	57	34	....	....	....	7.30	+4.2	18	4,150	se.	27	w.	15	8	9	14	5.7	0.0	0.0
Birmingham	700	11	48	29.16	29.91	−.07	69.0	−2.6	86	23	78	41	9	60	30	62	58	75	7.27	+4.2	19	5,284	e.	30	s.	11	7	8	16	6.2	0.0	0.0
Mobile	57	125	161	29.82	29.88	−.11	72.6	−1.3	92	22	80	50	10	65	24	67	65	82	7.91	+3.9	15	7,058	nw.	56	e.	2	6	19	6	5.3	0.0	0.0
Montgomery	223	100	112	29.66	29.91	−.08	70.8	−2.6	89	22	79	46	10	62	28	64	61	78	9.69	+5.9	16	4,821	se.	31	n.	8	7	11	13	6.1	0.0	0.0
Corinth	469	6	....	......	......	......	67.8	......	88	31	77	40	10	59	34	....	....	....	10.52	......	18	......	se.	....	......	....	2	21	8	....	0.0	0.0
Meridian	375	85	93	29.48	29.88	−.10	70.0	−1.1	88	22	79	43	10	61	32	63	60	78	9.07	+5.2	17	3,946	sw.	48	se.	2	7	13	11	5.8	0.0	0.0
Vicksburg	247	65	73	29.62	29.90	−.07	70.9	−2.0	92	31	79	47	10	63	28	65	63	84	9.47	+5.2	14	4,802	se.	38	se.	1	6	12	13	6.0	0.0	0.0
New Orleans	53	76	84	29.82	29.88	−.09	74.3	−1.1	91	29	82	57	10	66	26	68	66	78	9.10	+5.2	10	5,035	s.	33	ne.	2	12	14	5	4.3	0.0	0.0
West Gulf States.							**72.6**	**−0.2**										**73**	**3.69**	**−0.3**										**4.2**		
Shreveport	249	77	93	29.60	29.87	−.08	71.4	−1.8	93	31	81	46	9	62	29	64	61	75	4.68	+0.5	9	5,440	n.	33	w.	14	11	15	5	4.3	0.0	0.0
Bentonville	1,303	11	44	......	......	......	63.6	−2.8	88	31	74	35	9	54	35	....	....	....	9.20	......	15	......	......	....	......	....	12	6	3	....	0.0	0.0
Fort Smith	457	79	94	29.38	29.85	−.08	66.8	−2.9	89	31	76	40	9	58	36	61	57	76	8.87	+4.0	16	6,358	e.	56	w.	23	10	8	13	6.0	0.0	0.0
Little Rock	357	136	144	29.48	29.85	−.10	67.4	−2.9	89	31	76	40	9	58	33	61	57	76	10.50	+5.4	16	6,442	e.	49	s.	11	9	10	12	6.1	0.0	0.0
Brownsville	57	53	61	29.74	29.80	......	80.6	......	95	26	88	64	5	73	31	73	71	81	0.48	......	2	7,946	s.	36	s.	14	16	14	1	3.0	0.0	0.0
Corpus Christi	20	11	73	29.81	29.83	−.07	78.6	+2.1	93	2	84	62	3	73	31	72	69	76	0.09	−2.7	4	11,772	se.	48	s.	11	15	13	3	4.1	0.0	0.0
Dallas	512	109	117	29.30	29.84	......	73.0	......	95	30	83	46	9	63	30	....	....	....	1.35	......	6	7,437	se.	41	s.	11	11	16	4	4.7	0.0	0.0
Fort Worth	670	106	114	29.11	29.81	−.10	73.4	+0.2	97	30	84	46	9	63	29	63	57	62	0.54	−3.6	8	8,498	e.	39	s.	11	12	15	4	4.6	0.0	0.0
Galveston	54	106	114	29.81	29.87	−.07	76.0	+1.2	87	15	81	61	9	71	16	70	68	79	3.56	+0.3	5	9,230	se.	43	se.	1	15	14	2	3.7	0.0	0.0
Groesbeck	461	11	56	29.36	29.84	......	73.6	......	92	31	84	50	9	63	30	....	....	....	0.46	......	5	9,394	se.	46	w.	14	12	16	3	4.2	0.0	0.0
Houston	138	111	121	29.71	29.85	......	76.0	+0.5	91	30	85	57	10	67	25	....	....	....	3.89	......	7	6,903	se.	35	se.	30	19	8	4	3.2	0.0	0.0
Palestine	510	64	72	29.33	29.85	−.08	72.8	+0.1	92	31	82	48	9	63	27	64	60	70	2.12	−2.8	8	5,453	n.	34	sw.	11	14	13	4	4.7	0.0	0.0
Port Arthur	34	58	66	29.81	29.85	......	75.0	......	88	30	82	58	8	68	21	69	66	76	6.86	......	8	7,865	s.	35	n.	18	23	3	5	3.0	0.0	0.0
San Antonio	701	119	132	29.11	29.82	−.08	77.2	+2.4	96	31	88	58	5	66	31	66	60	62	1.33	−1.6	8	6,431	se.	44	nw.	29	15	13	3	3.7	0.0	0.0
Taylor	582	55	63	29.26	29.87	−.04	75.5	+1.2	93	29	86	53	9	64	31	....	....	....	1.51	−2.5	5	7,562	se.	42	s.	12	15	12	4	3.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, May, 1923*—Continued.

Districts and stations.	Elevation of instruments. Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Pressure. Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Temperature of the air. Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation. Total.	Departure from normal.	Days with .01, or more.	Wind. Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	°F. 62.7	°F. −2.2	°F.		°F.	°F.		°F.	°F.	°F.	°F.	% 66	In. 3.92	In. +0.2		Miles.								0-10 6.3	In.	In.
Chattanooga	762	189	213	29.11	29.91	−.08	65.2	−3.6	84	22	74	39	10	57	32	59	55	76	8.14	+4.5	19	5,370	ne.	40	nw.	8	5	7	19	7.1	0.0	0.0
Knoxville	996	102	111	28.88	29.92	−.07	65.2	−2.0	85	22	75	38	9	56	33	58	54	73	4.53	+0.8	19	4,825	ne.	31	s.	30	1	7	23	8.6	T.	0.0
Memphis	399	76	97	29.45	29.87	−.09	68.0	−2.6	86	31	76	44	9	60	24	61	57	74	6.16	+1.8	13	5,569	ne.	50	sw.	15	5	10	16	7.1	0.0	0.0
Nashville	546	168	191	29.34	29.92	−.06	65.6	−2.6	83	20	74	41	10	57	28	59	56	75	4.31	+0.8	18	7,042	e.	56	nw.	8	5	9	17	7.2	0.0	0.0
Lexington	989	193	230	28.86	29.91	−.08	63.0	−1.3	87	31	73	31	9	53	33				1.66	−1.9	13	10,215	ne.	60	nw.	8	7	9	15	6.4	0.5	0.0
Louisville	525	219	255	29.35	29.93	−.05	64.5	−2.1	85	19	75	33	9	54	34	55	48	61	4.68	+1.0	15	8,694	ne.	52	w.	8	6	11	14	6.4	T.	0.0
Evansville	431	139	175	29.44	29.91	−.06	64.8	−2.3	84	30	74	38	9	56	28	57	52	67	4.66	+1.2	17	8,776	ne.	53	w.	14	16	13	12	6.4	0.0	0.0
Indianapolis	822	194	230	29.04	29.92	−.05	60.6	−2.3	84	31	71	31	9	50	34	53	46	65	5.86	+1.9	11	10,137	ne.	48	nw.	9	7	13	11	6.0	1.2	0.0
Royal Center	736	11	55	29.12	29.92	.....	57.0	.....	85	29	69	29	9	46	35				4.62	.....	11	9,169	e.	44	nw.	9	8	6	17	6.3	4.1	0.0
Terre Haute	575	96	129	29.29	29.91	.....	62.4	.....	84	31	72	33	9	52	30	54	48	65	6.20	.....	13	6,793	ne.	38	w.	8	3	17	11	6.2	0.1	0.0
Cincinnati	628	11	51	29.24	29.92	−.07	61.2	−1.9	87	31	73	32	9	50	36	.....	48	65	2.34	−1.2	11	5,893	ne.	37	w.	8	6	11	14	6.1	T.	0.0
Columbus	824	179	222	29.07	29.93	−.05	59.8	−2.5	85	31	71	31	9	49	36	52	46	65	2.42	−1.3	9	8,781	e.	58	nw.	8	10	12	9	5.3	0.3	0.0
Dayton	899	181	216	28.97	29.92	.....	60.4	−2.5	88	31	72	31	9	49	38	52	45	63	2.56	−1.3	11	8,847	ne.	46	nw.	8	11	11	9	5.0	0.5	0.0
Elkins	1,947	59	67	27.92	29.94	−.06	57.8	−1.3	85	29	72	28	9	44	41	51	45	67	1.96	−2.0	12	4,291	w.	31	sw.	16	6	15	10	6.1	0.5	0.0
Parkersburg	638	77	84	29.29	29.95	−.04	62.2	−1.1	87	15	74	31	9	51	35	53	46	60	2.31	−1.2	7	4,008	n.	36	nw.	8	10	10	11	5.7	T.	0.0
Pittsburgh	842	353	410	29.04	29.94	−.05	60.1	−2.3	86	29	72	31	9	49	32	51	42	55	3.34	0.0	7	8,483	ne.	50	sw.	16	13	7	11	5.1	0.9	0.0
Lower Lake Region.							53.8	−3.7										65	3.03	−0.1										4.2		
Buffalo	767	247	280	29.13	29.93	−.01	52.6	−2.0	82	26	62	26	10	43	32	46	38	63	3.06	0.0	8	10,723	e.	68	sw.	17	17	6	8	3.8	2.2	0.0
Canton	448	10	61	29.46	29.93	.....	51.1	−5.1	78	8	62	26	6	40	37				3.20	+0.4	11	7,364	sw.	50	sw.	17	18	4	9	3.8	2.0	0.0
Oswego	335	76	91	.....	29.96	−.03	50.0	−5.2	78	20	59	30	11	41	35				1.98	−0.9	10	6,390	w.	29	w.	17	17	4	10	.....	0.5	0.0
Rochester	523	86	102	29.40	29.98	+.01	53.8	−3.3	83	26	64	30	10	43	39	46	38	58	2.69	−0.2	9	5,433	ne.	37	sw.	17	21	0	10	3.6	0.7	0.0
Syracuse	597	97	113	29.33	29.98	.00	53.1	−4.2	80	26	64	30	10	43	35				2.54	−0.8	10	7,472	nw.	47	s.	15	17	4	10	4.3	0.1	0.0
Erie	714	130	166	29.18	29.95	−.03	54.1	−2.7	84	15	63	32	10	45	29	48	41	62	2.62	−0.8	9	10,434	ne.	52	s.	15	18	4	9	3.7	1.7	0.0
Cleveland	762	190	201	29.13	29.96	−.02	54.5	−3.4	80	15	62	32	9	46	28	48	40	59	2.91	−0.3	8	9,872	ne.	47	w.	16	13	8	10	4.9	T.	0.0
Sandusky	629	62	70	29.27	29.96	−.02	54.0	−5.2	78	15	61	32	9	47	30				3.19	−0.1	8	7,024	ne.	39	nw.	8	9	12	10	5.3	T.	0.0
Toledo	628	208	243	29.28	29.96	−.01	55.4	−4.0	77	26	64	30	9	47	31	49	44	68	3.03	−0.2	9	11,277	ne.	48	sw.	16	18	7	6	3.8	4.0	0.0
Fort Wayne	856	113	124	29.02	29.94	.....	57.3	−2.9	85	29	69	30	9	46	36	50	44	66	4.25	.....	10	7,576	e.	34	nw.	9	10	10	11	5.3	1.5	0.0
Detroit	730	218	258	29.18	29.97	.00	55.7	−2.3	79	29	66	29	10	45	29	50	47	75	5.08	+1.8	9	8,539	ne.	42	sw.	15	19	3	9	3.9	6.0	0.0
Upper Lake Region.							51.7	−1.3										63	2.40	−1.0										4.1		
Alpena	609	13	92	29.33	30.00	+.03	47.7	−2.8	79	26	56	26	13	39	29	43	37	66	2.49	−0.8	8	8,149	se.	44	nw.	9	16	11	4	3.6	2.0	0.0
Escanaba	612	54	60	29.33	30.00	+.03	48.4	−1.6	72	27	56	26	13	41	21	42	36	63	0.76	−2.7	4	6,709	s.	45	ne.	6	18	7	6	3.6	T.	0.0
Grand Haven	632	54	89	29.27	29.95	−.01	54.5	0.0	84	31	66	30	9	43	34	48	42	64	3.06	−0.3	8	7,801	e.	44	nw.	9	13	10	8	4.3	4.8	0.0
Grand Rapids	707	70	87	29.20	29.97	.00	56.8	−2.2	84	29	69	30	9	44	33	48	40	56	3.70	+0.4	7	4,680	e.	26	w.	9	11	10	10	5.1	5.5	0.0
Houghton	684	62	99	29.26	29.99	+.02	50.1	+0.4	82	27	61	27	13	39	36				0.83	−2.5	10	6,826	e.	34	w.	2	15	8	8	4.5	0.5	0.0
Lansing	878	11	62	29.01	29.96	.....	54.6	−3.3	84	29	69	26	10	40	39	47	40	60	3.45	−0.1	8	4,379	e.	19	nw.	16	16	8	7	4.1	11.5	0.0
Ludington	637	60	66	29.27	29.97	.....	51.8	.....	84	31	61	28	13	42	33	46	41	68	3.32	.....	6	7,190	n.	42	n.	9	18	9	4	3.4	0.8	0.0
Marquette	734	77	111	29.21	30.02	+.02	49.4	+0.4	87	27	58	26	12	40	31	43	35	61	1.27	−2.0	8	5,704	nw.	22	nw.	8	15	6	10	4.4	T.	0.0
Port Huron	638	70	120	29.27	29.96	−.02	50.8	−4.4	72	15	60	24	10	41	31	44	38	66	4.14	+0.9	7	7,881	ne.	46	nw.	16	17	9	5	3.5	6.5	0.0
Saginaw	641	69	77	29.28	29.98	.....	53.4	.....	79	26	65	24	10	42	31	48	43	68	4.29	+0.2	8	6,260	ne.	34	ne.	16	14	9	8	4.1	9.0	0.0
Saulte Sainte Marie	614	11	52	29.32	30.02	+.07	49.4	+1.7	83	25	62	25	11	37	39	43	36	64	1.00	−2.2	5	5,598	se.	38	nw.	9	18	7	6	3.5	0.0	0.0
Chicago	823	140	310	29.07	29.96	.00	54.4	−1.4	79	19	62	31	9	47	26	47	40	63	3.46	+0.1	7	9,064	ne.	36	s.	19	9	16	6	5.0	0.6	0.0
Green Bay	617	109	144	29.30	29.96	+.01	55.2	−0.7	83	28	66	30	8	42	31	47	39	59	1.50	−2.1	5	8,067	se.	48	se.	19	11	13	7	5.0	0.2	0.0
Milwaukee	681	125	139	29.23	29.96	.00	52.5	−1.6	76	26	61	31	8	44	27	45	39	63	1.81	−1.6	7	6,873	ne.	38	n.	9	14	10	7	4.3	1.2	0.0
Duluth	1,133	11	47	28.76	29.98	+.02	48.9	+1.6	78	25	59	26	9	39	36	43	36	65	1.81	−1.7	7	7,997	ne.	38	ne.	19	18	6	7	3.6	0.8	0.0
North Dakota.							55.1	+1.0										57	1.35	−1.2										5.1		
Moorehead	940	50	58	28.93	29.94	.00	55.8	+0.7	86	31	68	23	12	44	37	48	38	54	1.85	−1.1	7	6,222	n.	28	n.	8	13	12	6	4.3	T.	0.0
Bismarck	1,674	8	57	28.18	29.96	+.04	56.2	+1.7	87	26	68	25	8	44	41	48	40	59	1.01	−1.5	7	7,333	se.	36	n.	9	8	15	8	5.4	T.	0.0
Devils Lake	1,482	11	44	28.37	29.94	.00	54.5	+1.8	86	27	67	24	8	42	38	46	38	59	2.04	−0.2	10	7,484	s.	39	ne.	9	13	11	7	4.5	T.	0.0
Ellendale	1,457	10	56	28.40	29.97	.....	54.4	.....	85	27	68	24	12	41	45	.....	.....	.....	1.79	.....	8	10,187	se.	45	n.	14	7	17	7	5.4	T.	0.0
Grand Forks	835	12	89	.....	.....	.....	55.2	.....	88	27	69	20	12	41	48	.....	.....	.....	2.78	.....	9	.....	se.	36	s.	5	17	7	7	.....	0.1	0.0
Williston	1,878	41	48	27.93	29.90	−.03	53.8	−0.2	89	26	67	21	8	41	38	45	36	56	0.50	−1.8	10	6,235	se.	37	se.	31	6	14	11	5.8	1.2	0.0
Upper Mississippi Valley.							60.9	−1.0										63	3.16	−1.1										5.7		
Minneapolis	918	102	208	28.94	29.92	.....	59.6	.....	86	31	70	30	8	50	28	.....	.....	.....	2.97	−1.0	10	8,345	se.	50	n.	8	12	5	14	5.8	0.5	0.0
St. Paul	837	236	261	29.05	29.95	+.01	58.6	+0.7	83	31	69	30	8	48	29	.....	.....	.....	2.28	−1.3	10	8,270	se.	60	s.	1	11	16	4	4.3	1.0	0.0
La Crosse	714	11	48	29.18	29.95	+.01	59.9	+0.6	87	29	72	33	9	48	38	.....	.....	.....	1.53	−2.2	5	3,611	se.	21	nw.	8	13	7	11	5.2	0.4	0.0
Madison	974	70	78	28.92	29.97	+.01	57.0	−0.6	80	27	67	30	9	47	32	48	41	59	1.90	−1.7	6	6,672	se.	33	n.	4	12	7	12	5.3	0.5	0.0
Wausau	1,247	4	.....	28.65	29.99	.....	55.2	.....	83	28	68	28	9	43	37	.....	.....	.....	1.56	.....	6	.....	se.	.....	.....	.....	21	0	10	3.8	T.	0.0
Charles City	1,015	10	49	28.87	29.95	+.01	58.3	−1.2	85	29	70	29	9	46	40	50	42	58	1.34	−3.6	12	5,284	se.	27	nw.	8	14	8	9	4.8	T.	0.0
Davenport	606	71	79	29.27	29.93	−.02	60.8	−0.5	84	31	71	33	9	50	31	52	45	61	3.60	−0.6	12	6,721	e.	40	ne.	11	7	10	14	6.1	T.	0.0
Des Moines	861	84	97	29.01	29.91	−.02	60.7	−0.6	85	31	70	32	9	51	30	53	46	62	4.78	+0.2	14	6,004	e.	32	nw.	8	7	13	11	5.8	T.	0.0
Dubuque	698	81	96	29.21	29.96	+.01	60.0	−0.3	85	29	70	32	8	50	34	50	40	52	1.86	−2.5	7	5,022	se.	37	nw.	8	6	14	11	6.3	T.	0.0
Keokuk	614	64	78	29.25	29.91	−.03	62.0	−1.8	85	31	72	35	9	52	33	54	46	61	2.37	−1.9	10	6,004	e.	44	nw.	11	3	13	15	6.7	T.	0.0
Cairo	358	87	93	29.50	29.88	−.08	65.0	−3.4	84	30	73	42	9	57	29	58	54	72	5.10	+1.3	15	6,719	ne.	39	s.	11	6	4	21	7.0	0.0	0.0
Peoria	609	11	45	29.27	29.93	−.03	61.0	−0.7	85	31	72	32	8	50	38	53	47	68	5.15	+0.9	9	5,360	e.	30	ne.	11	11	12	8	5.0	0.1	0.0
Springfield, Ill	644	10	91	29.22	29.89	−.06	62.3	−0.9	84	31	73	36	8	52	36	54	49	67	3.46	−1.0	12	6,650	e.	36	nw.	8	7	13	11	5.7	T.	0.0
Hannibal	534	74	109	29.33	29.90	−.04	62.5	−1.1	86	31	72	36	8	53	38	.....	.....	.....	2.05	−3.0	12	6,614	e.	32	nw.	8	5	13	13	6.5	T.	0.0
St. Louis	567	265	303	29.28	29.88	−.07	64.1	−2.8	84	31	73	38	8	56	35	56	51	67	5.85	+1.6	14	9,152	e.	54	se.	14	5	13	13	6.6	T.	0.0
Missouri Valley.							60.3	−1.3										66	3.25	−1.0										5.8		
Columbia, Mo	781	11	84	29.06	29.89	−.05	62.6	−1.9	87	31	72	36	9	53	40	.....	.....	.....	1.97	−2.9	15	5,965	e.	37	nw.	8	6	14	11	6.4	T.	0.0
Kansas City	963	161	181	28.87	29.89	−.03	63.0	−1.5	85	31	72	37	9	54	30	55	48	64	2.25	−2.9	13	8,312	e.	43	w.	11	11	12	8	5.2	0.0	0.0
St. Joseph	967	11	49	28.86	29.89	.....	62.2	.....	85	30	72	35	9	52	34	54	48	65	2.80	.....	16	6,499	se.	37	nw.	11	14	10	7	4.7	T.	0.0
Springfield, Mo	1,324	98	104	28.49	29.88	−.05	62.4	−2.2	85	31	71	34	9	54	35	57	53	76	4.55	−1.0	15	7,572	se.	36	e.	14	10	12	9	5.2	0.0	0.0
Iola	984	11	50	28.84	29.86	−.06	63.6	−0.9	88	11	74	34	9	53	35	.....	.....	.....	5.33	+0.3	15	5,152	n.	36	nw.	23	8	12	11	5.9	0.0	0.0
Topeka	987	92	107	.....	.....	.....	62.1	−2.9	84	29	72	34	9	52	34	.....	.....	.....	5.02	+0.1	15	7,555	e.	42	n.	12	11	7	13	5.4	0.0	0.0
Drexel	1,299	10	54	28.53	29.91	.....	58.6	.....	82	27	69	29	9	49	33	.....	.....	.....	3.33	.....	14	8,170	e.	42	se.	19	6	10	15	6.5	0.0	0.0
Lincoln	1,189	11	84	28.65	29.90	−.01	60.2	−2.7	83	27	70	33	9	50	36	52	46	64	3.31	−0.9	12	7,599	se.	43	nw.	19	7	8	16	6.4	0.0	0.0
Omaha	1,105	115	122	28.75	29.92	.00	60.9	−1.5	85	30	70	35	9	52	32	54	48	65	2.50	−2.0	13	6,377	se.	35	nw.	8	7	13	11	6.0	0.0	0.0
Valentine	2,598	47	54	27.22	29.92	+.02	55.4	−0.8	83	31	66	26	8	44	48	48	42	65	3.26	−0.1	12	8,268	s.	40	se.	31	8	13	10	5.6	0.0	0.0
Sioux City	1,135	94	164	28.73	29.94	+.02	59.2	−1.2	84	27	69	32	9	50	35	51	44	62	3.81	−0.6	15	9,138	e.	44	n.	8	8	10	13	6.0	0.0	0.0
Huron	1,306	59	74	28.56	29.96	+.04	57.6	+1.2	86	27	70	29	9	46	42	50	42	63	1.58	−1.3	10	7,435	se.	39	nw.	7	10	12	9	5.4	0.4	0.0
Pierre	1,572	70	75	28.27	29.92	+.01	58.5	+0.5	86	26	69	30	8	48	47	52	46	70	1.43	−0.7	9	7,371	e.	44	n.	7	8	8	15	5.8	0.0	0.0
Yankton	1,233	49	57	28.61	29.92	.00	58.1	−1.3	84	31	68	31	8	48	36	.....	.....	.....	4.00	+0.1	11	6,070	e.	31	nw.	19	6	13	12	6.3	T.	0.0

TABLE I.—*Climatological data for Weather Bureau stations, May, 1923*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with .01, or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Northern Slope.							**52.8**	**0.0**										**62**	**2.52**	**+0.1**										**5.6**		
Billings	3,140	5	....				56.0	.....	94	26	73	25	3	40	57	....	....	....	1.94	.....	11	.....	nw.	....	....	....	10	12	9	....	0.0	0.0
Havre	2,505	11	44	27.27	29.88	−.02	55.4	+2.0	92	26	70	24	15	41	47	46	38	61	1.23	−0.9	8	5,561	e.	48	s.	25	11	14	6	4.8	0.0	0.0
Helena	4,110	87	112	25.73	29.90	−.03	51.1	−0.5	80	25	62	29	15	40	36	42	34	59	2.15	+0.2	17	6,490	sw.	38	sw.	30	3	10	18	7.2	T.	0.0
Kalispell	2,973	48	56	26.86	29.90	+.02	50.8	−0.2	77	25	62	27	3	40	39	43	35	62	2.88	+0.8	17	4,248	nw.	30	sw.	1	7	16	8	5.5	T.	0.0
Miles City	2,371	48	55	27.40	29.93	+.02	57.6	+0.9	93	26	70	28	8	46	38	47	38	55	1.87	−0.1	8	5,310	s.	36	n.	6	12	9	10	4.9	0.0	0.0
Rapid City	3,259	50	58	26.55	29.94	+.04	54.5	+0.3	85	26	66	29	8	44	39	46	39	59	4.25	+1.3	17	6,523	se.	36	nw.	2	11	7	13	5.7	0.0	0.0
Cheyenne	6,088	84	101	23.95	29.87	+.02	50.3	0.0	78	31	61	26	15	40	32	43	37	67	2.58	+0.2	13	10,005	s.	70	w.	18	7	13	11	6.0	0.3	0.0
Lander	5,372	60	68	24.58	29.88	.00	52.6	+0.6	80	26	65	29	15	40	34	44	36	58	1.90	−1.0	9	4,407	sw.	44	sw.	25	11	15	5	4.8	2.8	0.0
Sheridan	3,790	10	47	26.04	29.91	.....	53.4		88	26	67	26	16	40	44	46	38	65	3.27	.....	14	4,877	nw.	33	nw.	14	12	12	7	5.1	T.	0.0
Yellowstone Park	6,200	11	48	23.82	29.90	−.01	45.8	−1.6	72	24	58	22	2	33	37	37	30	61	1.71	−0.2	16	5,569	s.	43	s.	19	6	12	13	5.9	0.6	0.0
North Platte	2,821	11	51	27.03	29.93	+.05	57.2	−1.5	83	31	68	30	16	46	44	50	44	69	4.08	+1.0	10	4,857	se.	27	se.	31	11	5	15	5.8	T.	0.0
Middle Slope.							**60.7**	**−2.1**										**66**	**4.70**	**+0.9**										**5.3**		
Denver	5,292	106	113	24.66	29.86	+.02	56.1	−0.1	86	31	67	29	15	45	30	46	37	58	1.83	−0.7	11	6,146	s.	40	nw.	10	9	14	8	5.1	T.	0.0
Pueblo	4,685	80	86	25.20	29.83	.00	58.4	−1.1	88	31	71	37	15	46	42	47	38	55	0.68	−1.0	6	5,516	e.	44	nw.	11	6	19	6	5.2	T.	0.0
Concordia	1,392	50	58	28.43	29.89	−.02	60.2	−3.5	81	11	70	32	9	51	36	54	50	72	5.48	+0.8	14	5,931	se.	44	nw.	19	10	8	13	5.6	0.0	0.0
Dodge City	2,509	11	51	27.32	29.90	+.03	60.8	−2.7	89	10	72	32	16	50	42	53	48	70	7.74	+4.4	13	8,611	se.	36	sw.	31	14	10	7	4.4	0.0	0.0
Wichita	1,358	139	158	28.44	29.85	−.05	62.6	−3.3	86	31	72	37	9	54	30	56	50	68	5.47	+0.5	13	8,668	s.	52	se.	21	9	12	10	5.2	0.0	0.0
Broken Arrow	765	11	52	29.04	29.86	.....	65.1	.....	86	11	74	40	9	56	30	....	....	....	6.68	.....	14	9,831	se.	50	se.	23	10	10	11	5.6	0.0	0.0
Muskogee	652	4	....	.....	.....		67.2	.....	92	31	78	36	9	57	30	....	....	....	8.11	.....	16	.....	w.	....	....	....	13	4	14	....	0.0	0.0
Oklahoma City	1,214	10	47	28.58	29.84	−.05	66.3	−1.8	94	11	76	40	9	57	32	59	55	72	7.01	+1.3	12	8,662	n.	40	n.	21	7	15	9	5.9	0.0	0.0
Southern Slope.							**71.0**	**+0.4**										**51**	**0.72**	**−2.0**										**3.1**		
Abilene	1,738	10	52	28.03	29.80	−.07	72.6	+0.7	102	29	85	47	9	60	31	60	53	58	0.88	−2.8	4	8,570	se.	44	sw.	14	18	10	3	3.6	0.0	0.0
Amarillo	3,676	10	49	26.16	29.83	−.01	63.8	−0.5	91	11	76	39	16	51	42	53	46	61	1.70	−2.0	8	9,666	n.	38	nw.	1	26	5	0	2.7	0.0	0.0
Del Rio	944	64	71	28.84	29.80	−.05	78.7	+1.8	100	27	89	52	2	68	36	....	....	....	0.22	−2.2	2	7,242	se.	34	e.	18	20	7	4	3.3	0.0	0.0
Roswell	3,566	75	85	26.23	29.76	−.06	68.8	−0.6	95	27	84	43	16	54	40	50	31	35	0.10	−1.1	3	7,230	s.	44	ne.	3	18	10	3	2.9	0.0	0.0
Southern Plateau.							**67.4**	**+1.5**										**32**	**0.26**	**−0.1**										**1.8**		
El Paso	3,762	110	133	26.06	29.72	−.06	74.0	+1.9	95	25	87	51	1	61	36	51	24	20	0.01	−0.3	1	10,151	w.	46	sw.	13	24	7	0	2.1	0.0	0.0
Santa Fe	7,013	38	53	23.18	29.74	−.07	55.8	+0.1	78	25	69	33	14	43	32	43	30	43	1.02	−0.1	5	5,195	sw.	30	sw.	21	21	5	5	3.0	0.3	0.0
Flagstaff	6,908	10	59	23.29	29.76	−.02	51.6	+0.9	77	9	68	22	1	35	45	37	....	39	0.32	.....	1	7,592	.....	37	s.	20	29	1	1	....	0.0	0.0
Phoenix	1,108	76	81	28.61	29.74	−.04	77.6	+1.8	104	9	94	50	1	61	44	56	37	30	0.08	0.0	1	4,282	w.	33	n.	13	26	5	0	1.6	0.0	0.0
Yuma	141	9	54	29.59	29.73	−.06	79.2	+3.0	109	9	96	52	1	62	44	59	42	34	0.00	0.0	0	4,244	w.	27	w.	30	30	1	0	0.9	0.0	0.0
Independence	3,957	9	41	25.86	29.84	.00	66.0	+1.5	90	8	81	39	20	51	37	48	29	28	0.20	0.0	1	6,278	nw.	34	sw.	17	27	3	1	1.5	0.0	0.0
Middle Plateau.							**57.4**	**+1.2**										**41**	**0.76**	**−0.4**										**4.0**		
Reno	4,532	74	81	25.41	29.88	−.03	55.2	+1.6	79	8	69	32	2	42	38	43	31	49	0.69	−0.1	5	5,881	w.	50	w.	25	17	10	4	3.4	T.	0.0
Tonopah	6,090	12	20	23.96	29.78	.....	56.6	.....	78	8	68	30	31	45	31	40	21	29	0.31	−1.1	4	7,109	nw.	40	nw.	30	13	14	4	3.7	T.	0.0
Winnemucca	4,344	18	56	25.54	29.90	−.01	54.8	+0.9	86	24	69	28	28	40	44	43	31	49	0.70	−0.3	9	5,649	sw.	44	nw.	17	15	9	7	4.1	T.	0.0
Modena	5,479	10	43	24.52	29.80	−.02	55.2	+0.7	82	9	71	23	1	39	46	40	23	36	0.32	−0.6	5	8,446	w.	51	s.	30	16	12	3	3.1	T.	0.0
Salt Lake City	4,360	163	203	25.52	29.84	−.02	59.4	+2.0	84	24	69	35	1	50	30	47	36	46	1.91	0.0	10	6,018	nw.	46	n.	10	13	10	8	4.8	0.0	0.0
Grand Junction	4,602	60	68	25.26	29.79	−.04	62.3	+0.7	87	26	75	33	1	50	35	46	31	38	0.62	−0.3	5	5,086	se.	42	s.	31	11	11	9	5.0	0.0	0.0
Northern Plateau.							**56.4**	**−0.3**										**55**	**1.30**	**−0.4**										**6.2**		
Baker	3,471	48	53	26.40	29.98	+.02	50.7	0.0	81	8	62	29	3	40	38	43	37	64	1.59	−0.1	10	4,905	nw.	31	sw.	8	4	10	17	7.0	T.	0.0
Boise	2,739	78	86	27.09	29.93	−.01	56.8	−.03	88	24	69	33	2	45	39	47	38	55	1.76	+0.5	12	4,378	nw.	30	w.	10	10	15	6	5.3	0.0	0.0
Lewiston	757	40	48	29.14	29.94	−.02	59.8	−1.0	91	8	72	35	3	48	45				1.03	−0.6	14	2,763	e.	20	w.	1	6	7	18	6.9	0.0	0.0
Pocatello	4,477	60	68	25.38	29.85	−.04	55.4	−0.1	83	24	67	33	1	44	37	44	33	51	1.32	−0.9	10	6,175	sw.	36	s.	31	9	8	14	6.0	0.0	0.0
Spokane	1,929	101	110	27.91	29.94	−.02	55.6	+0.1	82	8	66	34	1	45	36	46	36	53	0.75	−0.9	7	4,872	sw.	28	sw.	1	2	15	14	7.0	T.	0.0
Walla Walla	991	57	65	28.89	29.96	.00	60.0	−0.7	88	8	70	38	3	50	36	50	40	52	1.36	−0.5	10	4,024	s.	26	sw.	10	11	14	6	5.2	0.0	0.0
North Pacific Coast Region.							**54.0**	**+0.1**										**78**	**1.74**	**−0.7**										**7.4**		
North Head	211	11	56	29.83	30.06	+.03	50.8	−0.4	60	3	54	41	1	47	13	49	47	89	2.09	−0.3	20	10,243	nw.	56	s.	28	1	11	19	7.5	0.0	0.0
Port Angeles	29	8	53	30.03	30.06	.....	49.6	.....	70	4	57	36	31	42	24				1.27	0.0	10	5,043	nw.	26	w.	22	2	11	18	7.5	0.0	0.0
Seattle	125	215	250	29.92	30.05	+.04	54.1	−0.9	76	7	61	40	2	47	28	48	43	71	1.45	−0.5	14	6,609	s.	35	s.	1	3	11	17	7.5	0.0	0.0
Tacoma	213	113	120	29.82	30.04	+.02	54.7	+0.1	76	8	63	39	2	46	31	....	....	....	1.39	−1.2	15	4,865	sw.	32	w.	29	1	12	18	7.4	0.0	0.0
Tatoosh Island	86	9	57	29.94	30.04	+.03	49.8	+0.2	59	4	53	40	1	46	12	48	48	94	2.91	−1.2	18	8,280	w.	39	s.	28	1	3	27	9.0	0.0	0.0
Yakima	1,071	4																														
Medford	1,425	5	....	.....	.....	.....	.....	.....	....	....	....	....	....	....	....	....	....	....	.....	.....	....	.....	.....	....	....	....	....	....	....	....	....	....
Portland, Oreg.	153	68	106	29.88	30.04	+.01	57.6	+0.7	85	8	66	40	2	49	31	50	44	66	1.48	−0.9	16	3,961	nw.	30	sw.	1	3	7	21	7.7	0.0	0.0
Roseburg	510	9	57	29.52	30.07	+.04	57.0	+1.0	87	8	69	33	2	45	39	50	44	68	1.56	−0.5	12	2,377	n.	20	w.	8	8	18	5	5.2	0.0	0.0
Middle Pacific Coast Region.							**58.1**	**−0.4**										**68**	**0.35**	**−0.9**										**3.5**		
Eureka	62	73	89	30.04	30.11	+.06	51.7	−0.4	74	8	56	38	2	47	29	49	47	85	1.26	−1.3	11	5,422	n.	26	n.	22	6	11	14	6.5	0.0	0.0
Point Reyes	490	7	18	29.44	29.96	.....	50.0	−1.6	65	8	54	42	2	46	18				0.03	.....	2	23,139	nw.	65	nw.	30	12	9	10	4.6	0.0	0.0
Red Bluff	332	50	56	29.56	29.92	−.03	67.6	+1.3	93	15	80	46	26	56	37	54	43	47	0.33	−1.0	5	4,879	nw.	25	nw.	13	24	7	0	2.2	0.0	0.0
Sacramento	69	106	117	29.86	29.93	−.01	63.3	0.0	91	8	77	44	26	50	36	54	48	64	0.08	−0.9	2	6,436	s.	24	s.	17	25	5	1	1.8	0.0	0.0
San Francisco	155	208	243	29.82	29.99	.00	57.2	+0.4	81	14	64	47	2	50	28	50	47	76	0.06	−0.8	2	8,668	w.	34	w.	12	23	7	1	2.8	0.0	0.0
San Jose	141	12	110	29.86	30.01	.....	58.7	−2.0	89	8	72	37	2	45	42	....	....	....	0.02	−0.7	1	5,204	nw.	26	nw.	9	19	9	3	2.9	0.0	0.0
South Pacific Coast Region.							**63.4**	**+1.4**										**66**	**0.05**	**−0.6**										**2.6**		
Fresno	327	89	98	29.57	29.92	.00	67.1	−1.3	94	8	81	46	2	53	36	54	42	48	0.20	−0.4	2	7,522	nw.	35	nw.	25	25	3	3	1.6	0.0	0.0
Los Angeles	338	159	191	29.55	29.91	−.04	64.6	+2.4	99	9	74	51	31	55	32	56	51	70	0.00	−0.5	0	4,066	sw.	21	sw.	9	21	7	3	3.0	0.0	0.0
San Diego	87	62	70	29.81	29.90	−.05	63.2	+2.4	83	9	69	53	3	57	25	57	54	78	0.00	−0.4	0	5,316	w.	24	s.	11	23	4	4	3.2	0.0	0.0
San Luis Obispo	201	32	40	29.77	29.99	−.01	58.9	+2.2	95	8	71	39	31	47	37	50	44	69	0.01	−0.9	1	4,095	nw.	23	w.	30	22	7	2	2.5	0.0	0.0
West Indies.																																
San Juan, P. R.	82	9	54	29.90	29.98	.....	79.3	.....	92	30	86	70	19	73	18	....	....	....	1.13	−3.6	9	8,020	e.	35	e.	19	16	10	5	4.4	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97	29.70	29.82	−.02	80.6	0.0	92	2	87	71	21	74	18	75	74	85	5.84	−2.4	14	4,417	nw.	24	nw.	15	0	8	23	7.1	0.0	0.0
Colon	36	7	97	29.79	29.83	−.02	81.8	+1.4	91	...	87	73	21	76	17	77	75	83	11.18	−1.2	13	6,032	n.	24	n.	10	4	15	12	6.8	0.0	0.0
Alaska.																																
Juneau	80	11	54	29.85	29.94	.....	48.2	.....	67	14	57	32	1	40	27	44	39	72	3.24	.....	19	4,544	s.	31	s.	9	6	5	20	7.5	0.0	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, May, 1923.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	In.	In.	In.
St. Johns, N. F	125	29.75	29.89	−.09	44.5	+1.6	57.3	37.8	66	32	3.41	−0.25	0.0
Sydney, C. B. I	48	29.89	29.94	−.03	45.9	+0.7	54.9	36.9	72	30	5.54	+1.77	0.0
Halifax, N. S	88	29.81	29.92	−.06	49.7	+1.3	59.3	40.1	73	32	3.72	−0.54	0.0
Yarmouth, N. S	65	29.84	29.91	−.07	47.1	−0.5	54.7	39.5	64	31	2.90	−0.90	0.0
Charlottetown, P. E. I	38	29.87	29.91	−.05	45.5	−1.4	52.9	38.1	69	22	1.34	−1.57	0.0
Chatham, N. B	28	29.82	29.85	−.10	47.2	−1.3	57.6	36.8	74	27	1.83	−1.38	0.0
Father Point, Que	20	29.90	29.92	−.01	42.5	−1.5	50.4	34.7	72	26	5.46	+2.88	0.0
Quebec, Que	296	29.62	29.94	.00	50.5	+0.6	60.3	40.7	77	29	3.10	+0.02	T.
Montreal, Que	187	29.72	29.93	−.01	52.9	−1.8	63.3	42.6	77	29	3.23	+0.28	T.
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.68	29.94	.00	53.2	−1.7	65.3	41.1	86	26	2.66	+0.07	T.
Kingston, Ont	285	29.64	29.95	−.01	50.3	−2.6	58.7	42.0	74	31	3.07	+0.39	0.0
Toronto, Ont	379	29.55	29.96	−.02	51.6	−1.6	61.9	41.3	83	27	3.70	+0.66	1.5
Cochrane, Ont	930												
White River, Ont	1,244	28.66	29.98	+.03	44.9	−0.8	62.1	27.6	84	9	0.63	−1.32	0.0
Port Stanley, Ont	592	29.34	29.98	+.01	48.9	−4.2	59.5	38.3	75	22	2.33	−0.85	2.1
Southampton, Ont	656	29.25			46.4	−4.3	56.4	36.4	74	26	3.60	+1.16	14.0
Parry Sound, Ont	688	29.26	29.96	+.01	48.7	−2.4	60.9	36.5	77	20	3.86	+0.93	6.0
Port Arthur, Ont	644	29.29	30.00	+.04	46.5	+0.6	56.3	36.7	80	21	1.22	−0.93	0.0
Winnipeg, Man	760	29.11	29.94	−.02	54.4	+2.8	67.3	41.5	90	19	2.55	+0.27	0.2
Minnedosa, Man	1,690	28.13	29.94	−.02	51.8	+3.4	65.5	38.2	87	20	2.17	+0.72	T.
Le Pas, Man	860				47.5		61.8	33.2	86	13	0.71		0.7
Qu'Appelle, Sask	2,115	27.64	29.87	−0.7	52.2	+2.4	66.4	38.1	91	16	1.08	−0.57	0.0
Medicine Hat, Alb	2,144												
Moose Jaw, Sask	1,759				52.5		67.2	37.8	95	20	0.81		T.
Swift Current, Sask	2,392	27.33	29.93	+.01	52.7	+2.0	68.0	37.5	92	21	0.84	−0.92	0.0
Calgary, Alb	3,428												
Banff, Alb	4,521												
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.37	29.94	−.01	51.1	+3.5	64.8	37.5	85	22	1.24	−0.02	0.1
Battleford, Sask	1,592	28.15	29.88	−.04	54.1	+3.1	68.2	40.0	87	25	1.02	−0.60	2.0
Kamloops, B. C	1,262	28.63	29.91	+.02	57.6	−1.5	69.3	45.9	83	32	1.50	+0.26	0.0
Victoria, B. C	230	29.76	30.02	+.02	52.3	−0.2	58.8	45.9	67	40	1.03	−0.45	0.0
Barkerville, B. C	4,180	25.60	29.90	+.06	42.8	−2.7	53.3	32.3	64	22	3.73	+1.21	7.3
Triangle Island, B. C	680												
Prince Rupert, B. C	170												
Hamilton, Ber	151	29.88	30.04	−.02	68.3	−1.1	74.0	62.6	77	58	5.14	+0.48	0.0

LATE REPORTS, APRIL, 1923.

Barkerville, B. C	4,180	25.55	29.88	+.02	34.0	+0.9	45.1	22.9	60	4	0.55	−1.27	5.5
Kamloops, B. C	1,262	28.67	29.95	+.02	50.3	+1.4	63.7	36.9	83	21	0.49	+0.10	
Calgary, Alb	3,428	26.35	29.95	+.05	40.0	+0.4	55.8	24.2	82	−2	0.98	−0.34	7.5
St. Johns, N. F	125	29.68	29.82	−.07	32.8	−1.7	38.7	26.9	48	10	3.66	+0.50	4.0
Hamilton, Ber	151	29.96	30.12	+.07	65.9	+2.0	71.8	60.0	77	55	4.05	+0.13	

SEISMOLOGICAL REPORTS FOR MAY, 1923.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, July 3, 1923.]

TABLE 1.—*Noninstrumental earthquake reports, May, 1923.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
1923.	H. m.		° ′	° ′			Sec.			
May 4	22 45	San Luis Obispo	35 13	120 45	5	2	8,3	Faint	Felt by many	J. E. Hissong.
	?	San Bernardino	34 05	117 15						Press report.
8	5 02	Cholame	35 35	120 10	2	1	Few.	None	Felt by several	Union Oil Co.
		ILLINOIS.								
6	7 50?	Cairo	37 00	89 05	4	1	60 *ca.*	None	Felt by several	J. F. McGruder.
15	23 42	do	37 00	89 05	2	1	5 *ca.*	do	do	W. E. Barron.
		MONTANA.								
22	8 12	Helena	46 40	112 00	3,4	3	2,5,1	Faint	Felt by many	W. T. Lathrop.
	8 20	Deer Lodge	46 25	112 45	?	2			Severe	F. A. Steger.
		SOUTH CAROLINA.								
4	10 55	Due West	34 15	82 30	2	1	Brief.	Rumbling		E. R. Young.
		UTAH.								
14	12 00	Nada	38 10	113 15	5	2	10	Rattling	Felt by many	L. A. Culmsee.

TABLE 2.—*Instrumental seismological reports, May, 1923.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and description of stations, see REVIEW for January, 1923.]

ALASKA. *U. S. C. & G. S. Magnetic Observatory, Sitka.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km*	
May 2		e	16 28 08	18				
		M_E	16 28 42	11	*200			
		M_N	16 29 06	12		*200		
		F	16 43 ..	10				
4		O	16 26 46				1,210	P_E has characteristics of a smooth long wave phase, e_N very weak. Recorded on magnetograph.
		P_E	16 29 24	22	*1,200			
		e_N	16 30 09					
		S_N	16 31 33					
		L_E	16 32 02	24				
		eL_N	16 32 50	16				
		L_N	16 34 14	16				
		$M1_E$	16 33 46	17	*9,800			
		$M2_E$	16 39 14	15	*12,000			
		M_N	16 35 24	16		*9,500		
		C_E	16 43 ..					
		C_N	16 40 ..					
		F_E	18 14 ..					
		F_N	18 27 ..					
23		e	22 49 34					Wind tremors strong.
		L_E	22 55 57	21				
		L_N	22 56 04	22				
		M_E	22 57 40	20	*300			
		M_N	22 57 44	20		*200		
		C	22 59 ..					
		F_E	23 56 ..					
		F_N	24 07 ..					

ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923.			*H. m. s.*	*Sec.*	μ	μ	*Km*	
May 4		O	16 26 47	4			4,210	
		P_E	16 34 20					
		eP_N	16 34 24					
		S_E	16 40 19	22				
		eS_N	16 40 34					
		$L1_E$	16 43 28	30				
		$L2_E$	16 45 01	28				
		$L1_N$	16 44 20					
		$L2_N$	16 46 56	20				
		M_E	16 47 58	20	*100			
		M_N	16 48 ..	18		*100		
		F_E	17 22 ..					
		F_N	17 04 ..					

CALIFORNIA. *Theosophical University, Point Loma.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 21					50	50		Tremors during preceding 24 hours.
26					50	50		

COLORADO. *Regis College, Denver.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 4		P_N	16 41 ..					Times somewhat doubtful; signals indistinct.
		L	16 47 ..	35	*2,000	*2,000		
		M	16 51 ..					
		C	16 58 ..					
		F	17					
12		L_N	0 53 ..					Wavelets: somewhat doubtful as to being seismic.
		F_N	1 06 ..					
18		L_N	11 16 ..					Very small and indistinct: possibly not seismic.
		F_N	11 34 ..					

* Trace amplitude.

DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 2		e	16 40 ..					
		L	16 44 ..	10				
		F	17 *ca.*					
4		P	16 43 25				6,200	Minutes uncertain—time marks defective.
		S	16 51 12					
		SR1	16 55 00					
		L	17 00 35	30				
		L	17 09 ..	14				
		F	18 10 *ca.*					
4		P	22 45 14				7.300	Do.
		S	22 53 58					
		L?	23 06 ..					
		F	23 20 ..					
12		P	1 41 51					
		F	1 50 ..					
23		P	22 48 45					
		S	22 58 23					
		eL	23 14 ..					
		L	23 15 30	20				
		F	24 *ca.*					
30		e	9 00 00					
		L	9 09 ..	18				
		F	9 15 ..					

ILLINOIS. *U. S. Weather Bureau, Chicago.*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		P	10 50 40				9300	
		S	11 01 05					
		L	11 20 00					
		L	11 31 ..	28				
		L	11 36 ..	18				
		F	12 10 *ca.*					
2		P	16 34 44					L indiscernible.
		S?	16 38 51					
		F	17 20 *ca.*					
4		P	16 35 06				4,800	
		S	16 41 35					
		L	16 47 50					
		M_N	16 53 ..			*25,000		
		F	20 *postea.*					Lost in micros.
4		P	22 38 32				7,100	
		S	22 47 06					
		L	22 59 00	30				
5		F	1 *post.*					Micros.
5		P	15 15 10					
		F	15 35 *ca.*					
10		e	4 04 05					
		L	4 41 ..	15				
		F	5 30 *ca.*					
12		P	1 39 41					
		PR1	1 42 52					
		S	1 49 16					
		eL	2 12 30					
		L	2 36 ..	28				
		L	2 58 ..	18				
		F	3 40 *ca.*					
23		P	22 47 03				8,600	
		S	22 56 55					
		L	23 10 30	22				
24		F	2 30 ..					
25		eL	23 10 ..					
		F	24 *ca.*					
28		P	1 48 24				7,000	
		S	2 06 55					
		eL	2 29 ..					
		L	2 35 ..	30				
		L	2 47 ..	22				
		F	3 50 *ca.*					
30		P?	8 42 30				9,000	
		S	8 52 40					
		eL	9 02 ..					
		L	9 03 ..	18				
		F	10 *ca.*					
30		P	18 09 24				9,700	
		S	19 10 ..					
		eL	19 30 ..	22				
31		P	22 12 29				6,000	
		PR1	22 14 55					
		S	22 19 33					
		L	22 25 12	22				
		F	23 20 *ca.*					

TABLE 2.—*Instrumental seismological reports, May, 1923*—Continued.

MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 4		e_E	16 37 28	3				Tremors of 3 sec. per. are superimposed on L, particularly on $L1_E$ and $L2_N$.
		S_E	16 43 49	30				
		S_N	16 43 45					
		e_E	16 46 06					
		e_N	16 46 36					
		$L1_E$	16 52 49	32				
		$L2_E$	16 55 52	20				
		$L3_E$	16 57 13	14				
		$L1_N$	16 50 36	32				
		$L2_N$	16 55 02	20				
		$L3_N$	16 56 18	14				
		M_E	16 57 25	16	*1,200			
		M_N	16 57 55	16		*800		
		C	17 02 ..	13				
		F_E	17 43 ..					
		F_N	17 40 ..					

CANAL ZONE. *Panama Canal, Balboa Heights.*

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		P_E	16 37 22				340*ca.*	Probably NW.
		P_N	16 37 18					
		S_E	16 37 58					
		S_N	16 37 54					
		M_E	16 38 00		*500			
		M_N	16 37 58			*500		
		F_E	16 41 00					
		F_N	16 43 45					
1							340?	Very slight tremors between 23:00:00 and 23:02:18.
17								Very slight tremors on NS component between 22:55 and 22:58.

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 4		e_E	17 40 49	18				Nothing definite.
		e_N	17 42 43					
		e_N	18 01 16	24				
		F	18 16 ..					
4		e_E	23 38 27	12	*100			
		e_N	23 29 55	8				
		e_N	23 38 53			*100		
		F	23 40 ..					

VERMONT. *U. S. Weather Bureau, Northfield.*

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*
May 4		P	16 35 46				5,800
		S	16 43 10				
		L?	16 52 ..				
		L	16 54 30	14			
		F	17 30 *ca*				
23		eL	23 11 ..				
		L	23 19 ..	16			
		F	24 *ca.* ..				

CANADA. *Dominion Observatory, Ottawa.*

INSTRUMENTS—DETERMINED CONSTANTS.

Instrument.	T_0—	r	v	ε	Comp.	l	Determined.
I	5.5		120	2:1	N-S.		Apr. 4, 1923
II	5.3		120	18:1	E-W.		May 3, 1923
17	12.0		250	20:1	E-W.	44.5	Do.
23	12.0		250	5:1	E-W.	42.0	Do.[1]
D	37.2			13:10	E-W.		Feb. 7, 1923
D	36.1			13:10	NS.		Do.
W			160		V.		May 3, 1923

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 1		e	10 55 ..					
		e	11 01 ..					
		e(S)	11 10 38					
		eL	11 17 30					
		L	11 34 44					
		F	12 05 ..					
2		e	16 34 52					
		e	16 36 15					
		eL	16 41 30					Irregular small periods.
		L	16 42 *to*					
		L	17 05 ..					
		F	17 30 *ca*					

*Trace amplitude.

[1] Damping ratio on No. 23 was made 5:1 on May 3. Previously it had been 10:1. This ratio is being varied for experimental purposes.

CANADA. *Dominion Observatory, Ottawa*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 4		*O*	16 26 34				5,520	Epicentre from Harvard, Strasbourg, and Ottawa, is Kodiak, Alaska.
		P	16 35 35					
		PR1M	16 37 34					
		PR2M	(16 38 07)					
		S	16 42 45					
		i	16 45 08					
		SR1	16 46 37					
		SR2	(16 47 30)					
		eL	16 49 ..	49	360			
		M1M	16 53 08	25	412			
		M2M	16 56 30	15	307			
		L	17 25 *to*					
		L	20 05 ..					
		F	20 30 *ca*					
4		*O*	(22 26 50)				(8,100)	
		(P)	22 38 20					
		(S)	22 47 41					
		(SR2)	22 56 ..					
		eL	23 01 ..					
		L	23 10 ..					
5		L	0 40 ..					
		F	1 15 ..					
5		eL	9 57 30					
		F	10 04 ..					
5		e	15 17 12					
		eL	15 23 ..					
		L	15 27 ..					
		F	16 00 ..					
8		e	19 23 00					Very faint traces only.
		e(S?)	19 27 22					
		eL?	19 32 ..					
		L	19 34 ..					
		L	19 46 *to.*					
		L	20 07 ..					
		F	20 18 ..					
10		e	4 01 32					
		e	4 10 00					
		e	4 11 41					
		e	4 13 32					
		e	4 19 26					
		eL	4 47 *to.*					Very small amplitudes.
		L	5 04 ..	19				
		F	6 20 *ca.*					
11		e?	(8 42 52)					
		e	8 44 00					
		e	8 49 37					
		e	8 54 ..					
		L	9 20 *to*	35				
		L	9 38 ..	19				
		F	10 *ca.*					
12		e	1 41 30					
		e	1 43 16					
		e	1 55 ..					
		e	2 08 ..					
		eL	2 22 ..					
		L	2 29 ..	44				
		L	2 40 *to*					
		L	2 59 ..	22				
		L	3 02 *to*					
		L	3 27 ..	21				
		F	4 00 *ca.*					
15		*O*	21 43 00				(7,600)	
		(P)	21 54 00					
		(S)	22 03 00					
		(eL)	22 09 30					
		L	22 20 ..					
		L	22 23 *to.*					
		L	22 50 ..	16				
		L	22 51 *to.*					
		L	23 05 ..	16				
		F	23 35 ..					
16		e	(18 27 28)					
		e	18 34 00					
		e	18 39 36					
		eL	19 04 30					Small sinusoidal L waves.
		L	19 11 ..	19				
		L	19 19 *to*					
		L	19 43 ..	16				
		F	20 00 ..					
23		*O*	22 37 21				7,580	
		PM	22 48 20					
		SM	22 57 19					
		eL	23 05 22					
		M1	23 14 ..					
		M2	23 20 30	18				
		M3	23 23 12	18				
		L	23 26 *to.*					
24		L	0 06 ..	15				
		L	0 06 *to*					
		L	2 06 ..					
		F	2 45 *ca.*					
25		e	22 45 45					On N-S of No. 17 only.
		e?	22 52 15					
		eL	22 58 ..					
		L	23 05 ..	34				
		L	23 15 ..	17				
		F	24 00 *ca.*					

TABLE 2.—*Instrumental seismological reports, May, 1923*—Continued.

CANADA. *Dominion Observatory, Ottawa*—Continued.

Date			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
1923. May 26		*O*	3 29 41					
		P	3 37 34					
		S	3 43 48					
		eL	3 49 30					
		L	4 00 ..					
		L	4 07 ..	21				
		F	4 55 ..					
26		e	9 13 30					
		e	9 19 ..					
		eL	9 35 ..					
		L	9 41 ..	30				
		L	9 54 ..	20				
		F	10 45 *ca*					
28		e(P)17.	1 48 45					
		eL	2 05 40					
		L	2 37 ..	30				
		L	2 42 ..	25				
		L	2 50 *to*					
		L	3 48 ..	15				
		F	4 00 *ca.*					
30		e(P)17.	8 48 23					
		eL	8 57 ..					
		L	9 01 ..					
		L	9 16 .:					
		F	10 00 ..					
30		eL–17.	16 02 ..					
		L	16 11 *to*					
		L	16 18 ..					
		F	16 25. ..					
30		i	18 14. 30					
		L	18 25 ..					
		L	18 27 ..	15				
		L	18 36 *to*					
		L	19 01 ..	15				
		F						Lost in changing sheets.
31		e	6 19 52					
		e	6 26 ..					
		eL	6 35 ..					
		L	6 46 *to*					
		L	6 54 ..	23				
		L	6 54 *to.*					
		L	7 16 ..	16				
		F	7 35 ..					
31		*O*	22 05 48				3,380	
		P	22 12 19					
		S	22 17 28					
		eL	22 20 ..					
		L	22 21 30					
		L	to 25 ..	21				
		L	22 29 *to*					
		L	22 54 ..	16				
		F	25 24 ..					

CANADA. *Dominion Meteorological Service, Victoria.*

Date			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
1923. May 1		P	11 15 26	6				
		L	11 36 34	36				
		M	11 41 30	36		13		
		F	12 49 29					
2		P	16 24 29	10			340	Probably off Oregon coast.
		S	16 25 07	12				
		L	16 25 45	12				
		M	16 27 57	8	42			
		P	16 24 35	7			270	
		S	16 25 05	11				
		L	16 25 57	10				
		M	16 26 50	10		48		
		F	17 53 07					
			VERTICAL.					
		P	16 24 32	3				
		M	16 27 47	11	6			
		F	16 39 09					
4		P	16 31 31	12			2,540	Alaska.
		L	16 35 39	20				
		M	16 37 31	20		564		
		F	20 46 46					
		P	16 31 30	8			2,550	
		L	16 35 39	16				
		M	16 37 56	20	384			
		F	20 20 51					
			VERTICAL.					
		P	16 31 30	3				
		L	16 35 37	15				
		M	16 37 56	15	17			

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

Date			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
1923. May 4		P	22 40 21	5			8,370	Probably off South American coast.
		S	22 49 59	8				
		L	23 07 28	20				
		M	23 21 09	11	8			
		F	0 28 01					
		P	22 40 18	6			8,460	
		S	22 50 01	10				
		L	23 07 34	30				
		M	23 19 36	15		13		
		F	0 25 41					
5		L	9 41 50	12				
		M	9 44 31	7	3			
		F	9 56 43					
		L	9 41 08	15				
		M	9 42 43	8		2		
		F	9 56 01					
5		P	15 05 56	6			1,350	
		L	15 08 19	15				
		M	15 09 04	13	12			
		F	15 49 04					
		P	15 05 56	6			1,100	
		L	15 07 54	20				
		M	15 10 04	10		9		
		F	15 34 02					
8		L	19 16 46	15	5			
		M	19 19 09	15				
		F	20 06 59					
		L	19 16 42	12				
		M	19 19 14	16		6		
		F	20 07 56					
10		P_E	4 07 25	8				Italy?
		P_N	4 07 25	8				
		L_N	4 54 33	28				
11		P	8 47 29	7				Do.
		L	9 04 36	37				
		M	9 08 34	15	4			
		F	9 35 44					
		P	8 47 29	5				
		L	9 04 39	30				
		M				1?		
		F	?9 40 09					
12		P	1 50 50	8			10,490?	
		S	2 02 10	25				
		L	2 18 10	30				
		M	2 39 35	20	6			
		F	3 40 52					
		S	2 01 28	12				
		L	2 18 30	20				
		M	2 43 30	18		5		
		F	3 39 00					
15		P	21 51 06	5				
		L	22 09 15	18				
		M	22 12 41	16	2			
		F	22 31 43					
		P	21 51 05	7				
		L	22 09 19	15				
		M	22 12 43	15		2		
		F	22 35 51					
20		P	20 01 00	3				
		L	20 12 46	18				
		M	20 14 15		3			
		P_N	20 01 05	3				
		L_N	20 11 15	30				
23		P	22 45 18	5			5,050	
		S	22 52 03	18				
		L	23 00 34	18				
		M	23 03 00	20	23			
		F	2 33 58					
		P	22 45 25	5			4,900	
		S	22 52 02	13				
		L	23 00 33	18				
		M	23 04 37	15		18		
		F	2 58 31					
25		L	23 12 08	18				
		M	23 23 08	16				
		F	23 37 38		3			
		L	23 12 25?	22				
		M	23 19 46	20		4		
		F	23 41 38					
26		P_E	3 33 14	5				
		L_E	3 47 48	10				

TABLE 2.—*Instrumental seismological reports, May, 1923.*—Continued.

CANADA. *Dominion Meteorological Service, Victoria*—Continued.

1923.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
May 25		P	3 33 11	5			2,510?	
		S	3 37 17	10				
		L	3 46 19	12				
		M	3 51 39	12		1		
		F	4 40 49					
26		L	9 24 29	12				NS component too small to measure.
		M	9 30 59	15	2			
		F	9 37 54					
28		P	1 48 21	10				
		L	2 06 39	18				
		M	2 48 06	20	4			
		F	4 09 34					
		P	1 48 13	8				
		L	2 17 12	20				
		M	2 47 31	16		3		
		F	3 51 44					
28		Le	8 55 02	.. 16				
		Ln	8 57 02					
30		S	8 46 18	11				
		L	8 57 03	20				
		M	9 04 15	16	6			
		F	9 21 58					
		P	8 39 16	5			5,270	
		S	8 46 13	6				
		L	8 57 20	18				
		M	9 03 02	18		10		
		F	9 39 43					
30		P	18 05 50	5			4,940	
		S	18 12 29	10				
		L	18 20 43	25				
		M	18 27 02	20	12			
		F	19 27 46					
		P	18 05 48	5			5,120	
		S	18 12 37	10				
		L	18 21 10	35				
		M	18 29 39	20		9		
		F	19 24 58					
31		P	22 13 47	6			10,380?	
		S	22 25 02	10				
		L	22 37 37	40				
		M	22 41 27	20	7			
		F	23 39 15					
		L	22 38 57	20				
		M	22 42 07	12		3		
		F	23 18 37					

Reports for May, 1923, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.

HAWAII. *U. S. C. & G. S. Magnetic Observatory*, Honolulu.

MASSACHUSETTS. *Harvard University*, Cambridge.

MISSOURI. *St. Louis Unversity*, St. Louis.

NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.

CANADA. *Meteorological Service of Canada*, Toronto.

TABLE 3.—*Late reports (instrumental).*

DISTRICT OF COLUMBIA. *Georgetown University, Washington.*

1923			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Mar. 1		eL?	8 51 00					Ill defined; heavy micros.
		L	9 03 09	16				
		F	9 35 ..					
2								Quake about 17*h*. lost changing sheets.
11		e_E	23 26 00					e_E, but not e_N, might be taken for L; very heavy micros.
		e_N	23 26 16					
		F	23 50 ..					
15		eP_E	6 08 11					Very heavy micros.
		eP_N	6 08 06					
		S_E?	6 12 10					
		S_N?	6 12 14					
		eL_E	6 17 24					
		eL_N	6 16 06					
		F	6 50 ..					
16		e_E	22 23 11					Difficult; very heavy micros
		e_N	22 23 33					
		L	23 22 06	18				
		L	23 30 05	16				
		L	23 34 05	20				
		F?						Micros.
18		e_E	20 44 ..					Difficult; heavy micros.
		e_N	20 44 ..					
		F	20 55 ..					
19		e_E	11 22 24					Heavy micros; NS poorly defined.
		S_E?	11 28 14					
		eL_E?	11 30 12					
		L_E	11 31 00	19				
		L_N	11 31 29	19				
		F	12 *ca*					
24		e	12 59 ..					Very heavy micros.
		S	13 06 26					
		eL_E	13 18 24					
		eL_N	13 18 00					
		L	13 41 00	22				
		M_E	13 47 38	18	*1,500			
		F	14 45 ..					
Apr. 13		P	15 42 27					Very heavy micros.
		S_E?	15 51 52					
		eL_E	16 00 24					
		L_E	16 09 ..	29				
		L_N	16 09 ..	18				
		M_E	16 20 ..	17	*1,300			
		F	17 *ca*					
23		eL_E?	4 18 42					Heavy micros.
		L_E	4 23 27	16				
		F	4 40 ..					
24		P_E?	23 00 ..					Do.
		P_N?	23 00 38					
		S_E	23 07 05					
		S_N	23 07 05					
		F	23 35 ..					
25		e	19 50 ..					
		S?	19 54 29					
25		S	20 10 31					P in cauda in preceding.
		F	20 50 ..					

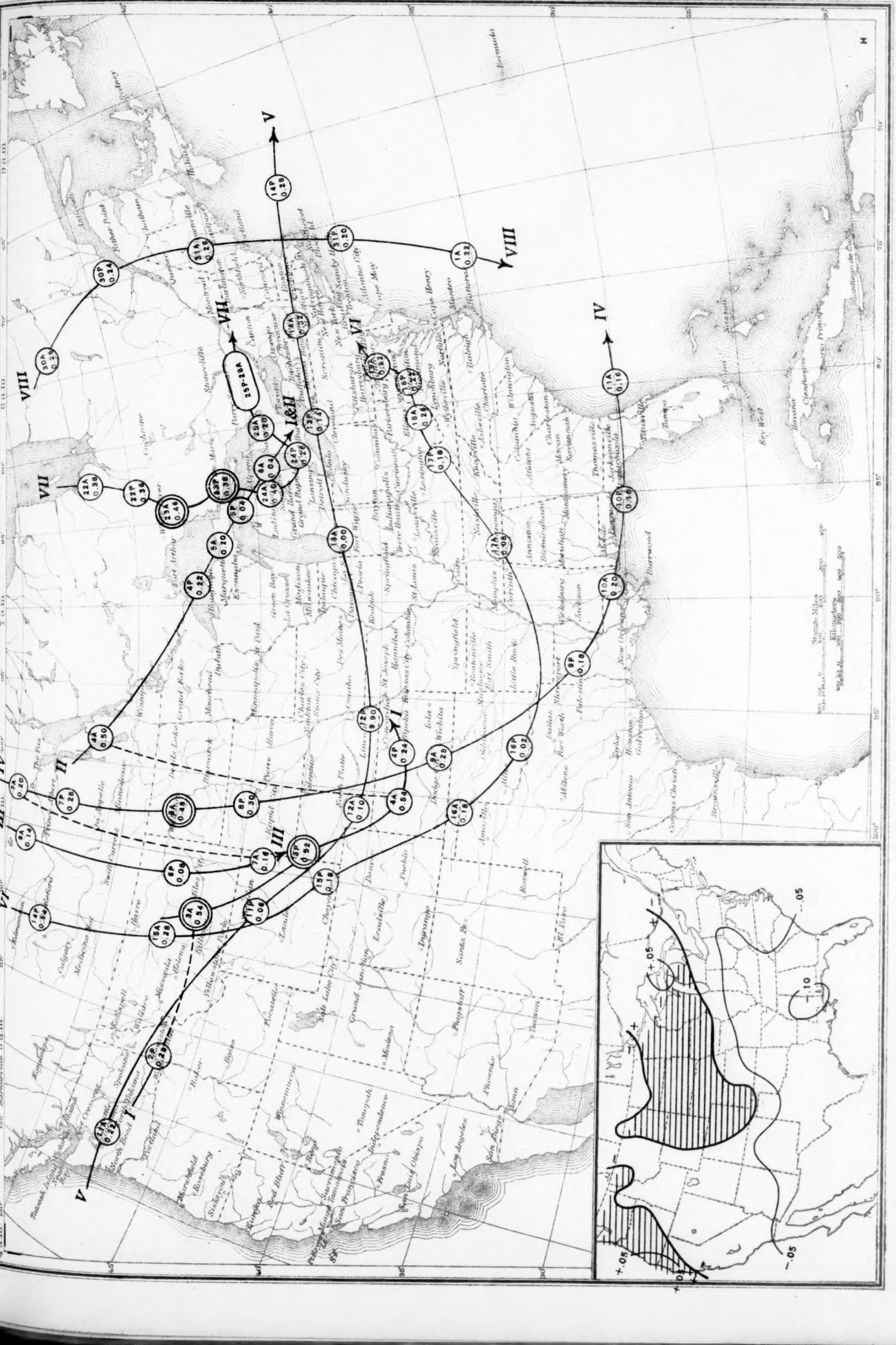

(Plotted by Wilfred P. Day.)

Chart II. Tracks of Centers of Cyclones, May, 1923. (Inset) Change in Mean Pressure from Preceding Month.

(Plotted by Wilfred P. Day.)

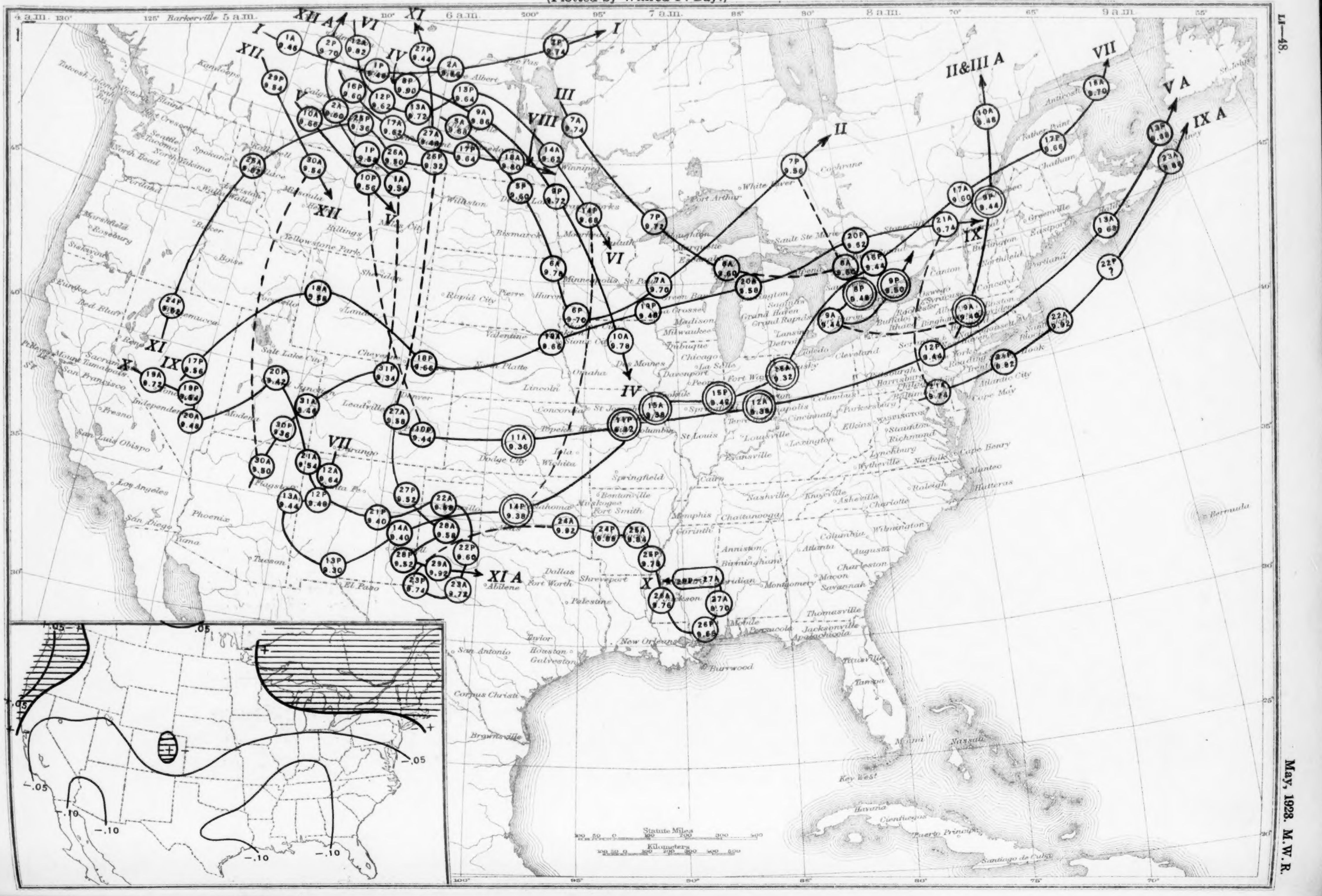


Chart III. Departure (°F.) of the Mean Temperature from the Normal, May, 1923.

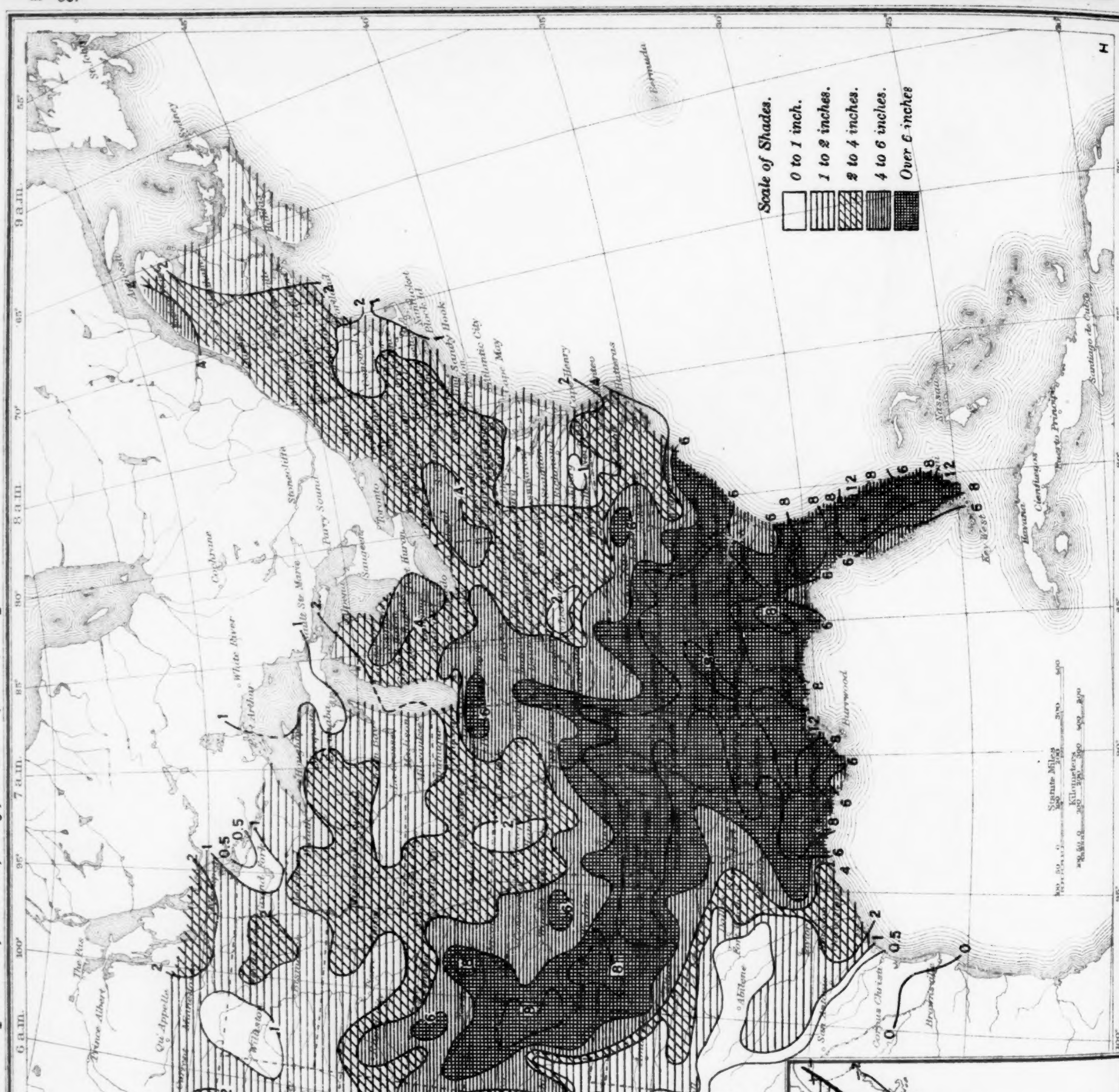


Chart IV. Total Precipitation, Inches, May, 1923. (Inset) Departure of Precipitation from Normal.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, May, 1923.

Chart V. Percentage of Clear Sky between Sunrise and Sunset, May, 1923.

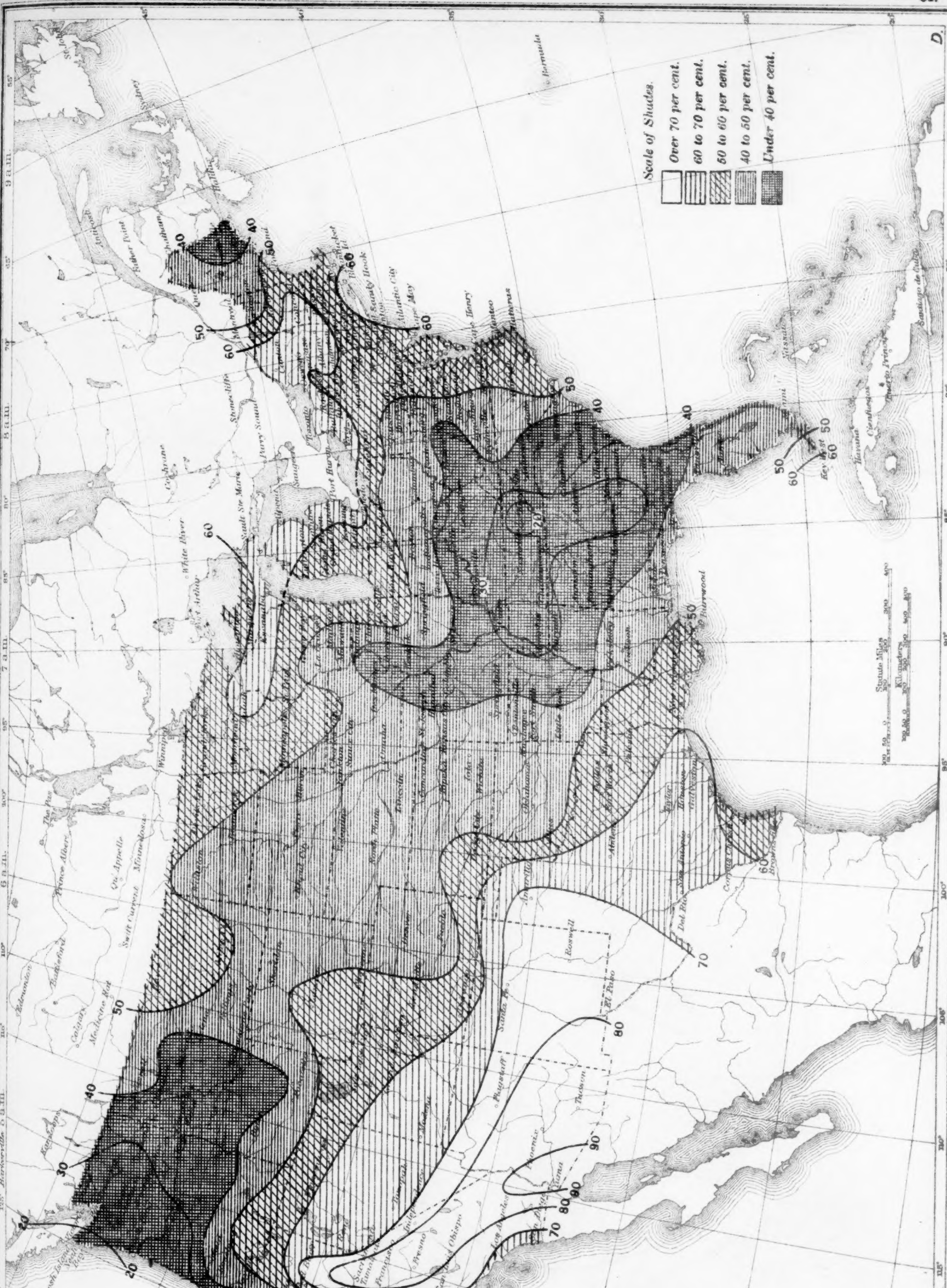


Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, May, 1923.

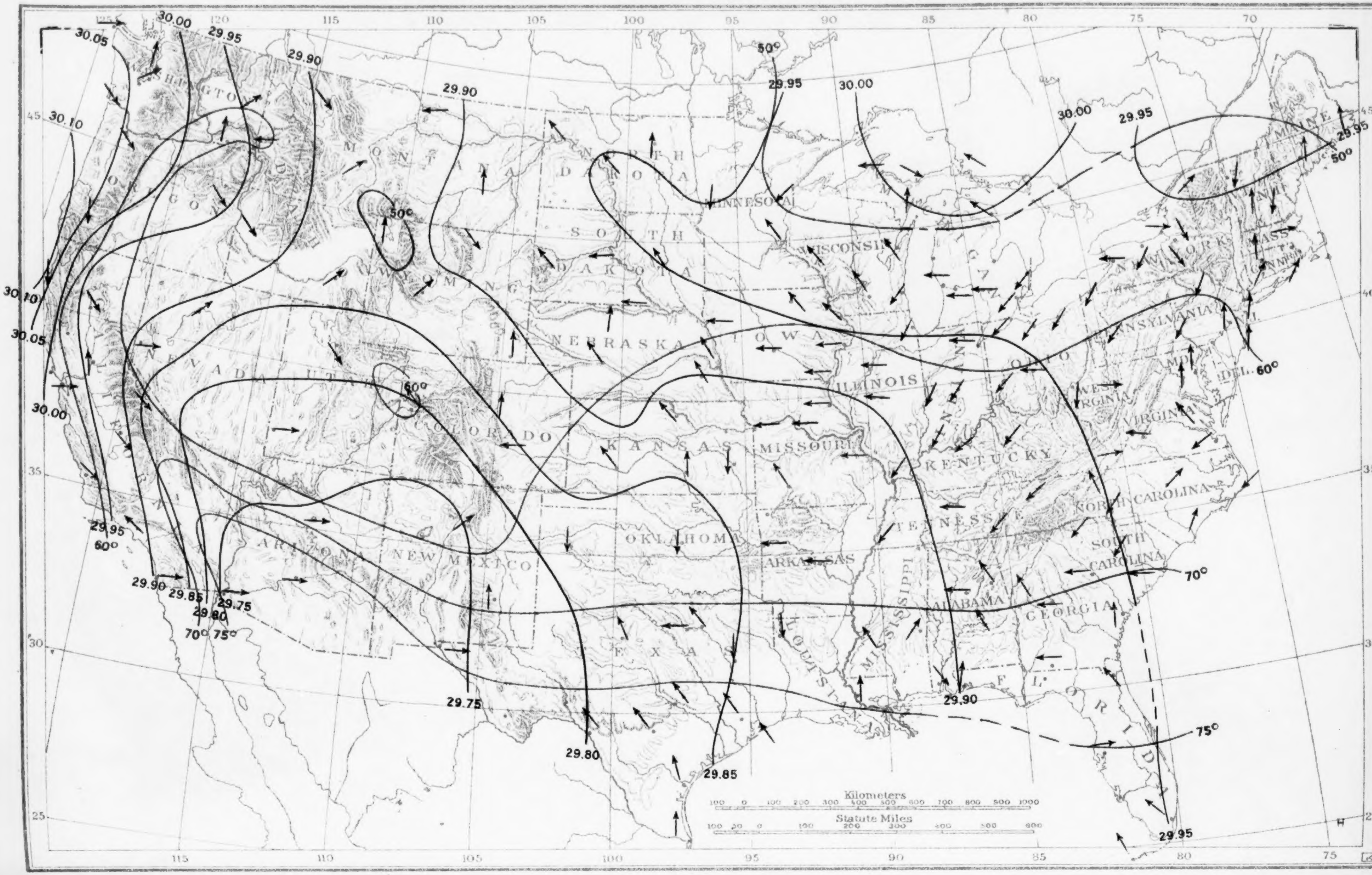
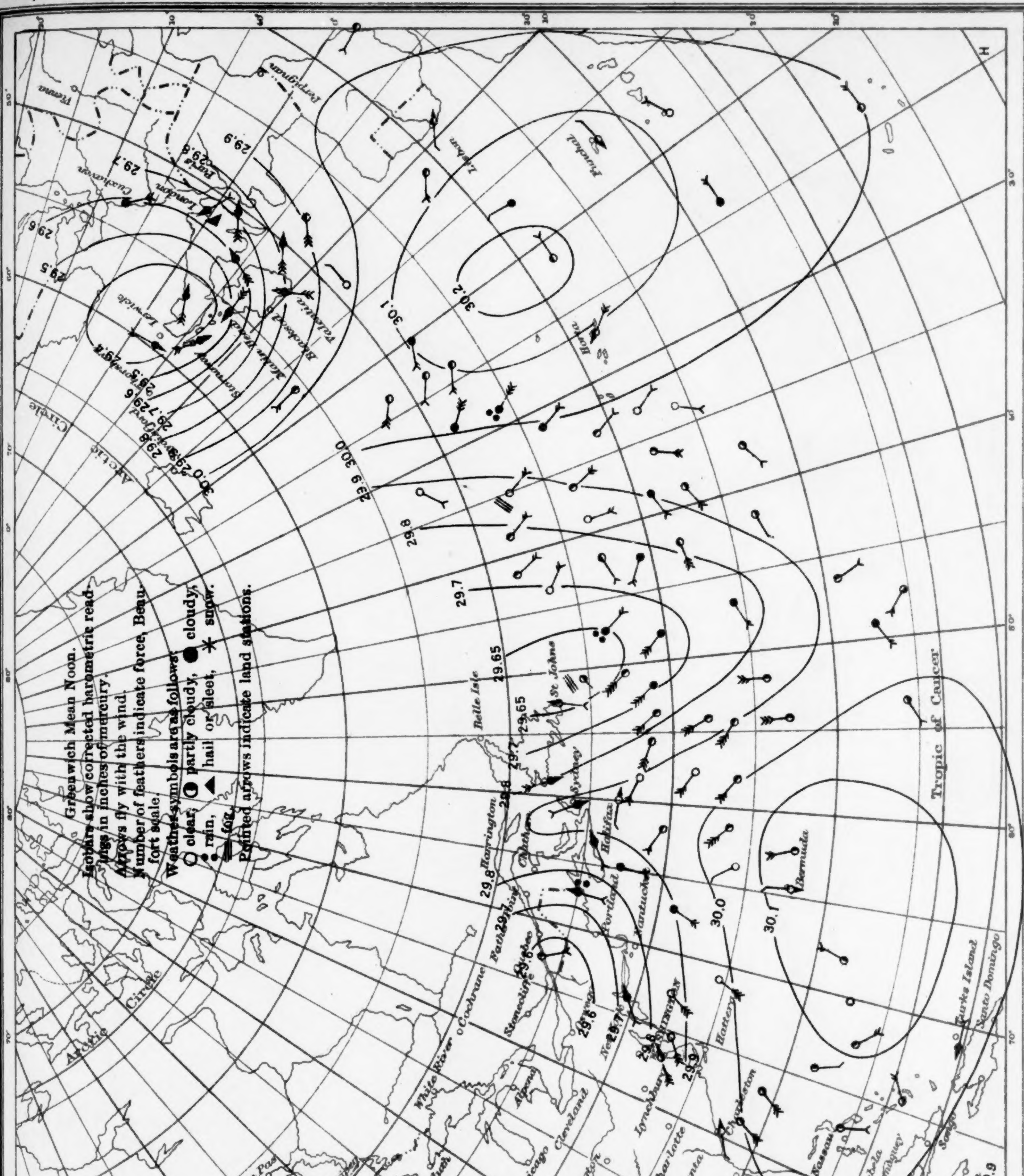


Chart VIII. Weather Map of North Atlantic Ocean, May 12, 1923.
(Plotted by F. A. Young.)



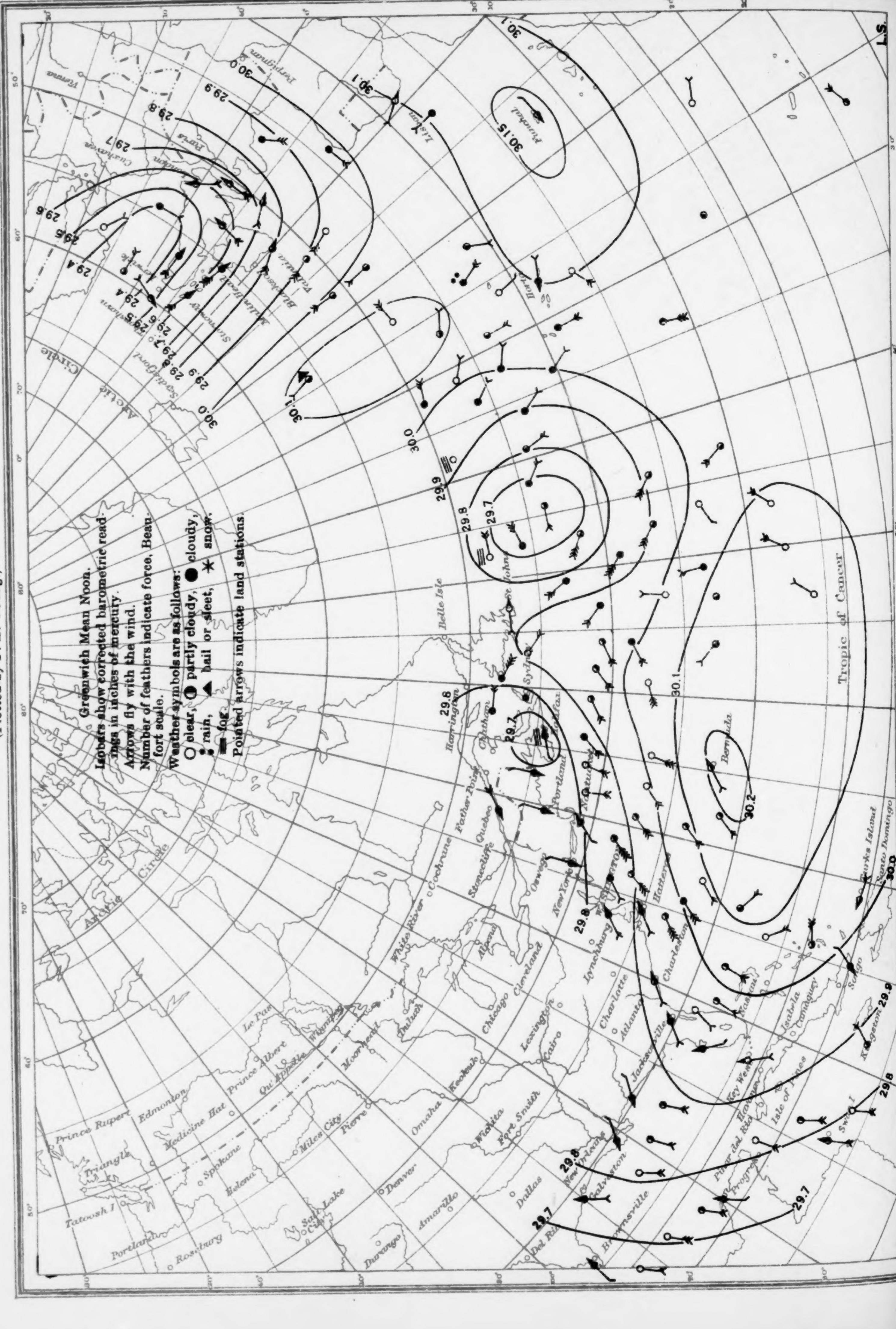


Chart IX. Weather Map of North Atlantic Ocean, May 13, 1923.
(Plotted by F. A. Young.)